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ALOFT Flight Test Report

by
James D. Ross
and
L. M. Johnson
Systems Development Department

OCTOBER 1977

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FOREWORD

The successful results of tests on a fiber optic data link, manufactured by International Business Machines (IBM) under Contract No. N00123-76-C-1665 for the Naval Electronics Laboratory Center (NELC), San Diego, CA, begun in January 1973, led NELC to propose a further investigation of fiber optic data transmission at full-scale system level in an A-7 aircraft. The proposal to design, install, and test such a system was approved by the Assistant Secretary of the Navy for Research and Development and funded, in March 1974, by the Naval Air Systems Command, as a 2-year program. AirTask A360360G/003C/4W41X1-001 provided for the implementation of the A-7 Airborne Light Optical Fiber Technology (ALOFT) Demonstration with NELC as the lead activity.

The Naval Weapons Center (NWC), China Lake, CA, had the capability of making ground preflight tests with the simulator in their A-7E Systems Integration Laboratory, the means to install modifications, and could conduct well-instrumented flight tests and provide systems engineering and maintenance support. For these reasons, the preflight and flight test demonstration was assigned to NWC where the work was carried out during the period from January through October 1976.

This report documents significant results of the demonstration as a matter of record for NELC. It deliberately avoids any classified aspects. This complies with NELC's request that it be kept unclassified because the state-of-the-art in the development of fiber optics technology makes it desirable that potential manufacturers have ready access to the basic findings of these tests.

The report has been reviewed for technical accuracy by J. Hall and R. Bruckman.

The following members of the A-7E Program Office and the Tactical Software Engineering Division also were responsible for conducting the ALOFT Flight Test Program and made contributions to this report: J. Basden, R. Westbrook, L. Thompson, J. Williams, and W. Chartier.

Released by
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Under authority of
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20. Abstract

(U) *ALOFT Flight Test Report*, by James D. Ross and L. M. Johnson. China Lake, Calif., Naval Weapons Center, October 1977. 112 pp. (NWC TP 5954, publication UNCLASSIFIED.)

(U) This report documents the results of a test and evaluation program to verify the operational utilization of fiber optic technology in an operational attack aircraft. The program involved configuring an A-7 aircraft with an airborne light optical fiber technology (ALOFT) system consisting of special signal conditioning hardware and fiber optic bundles.

(U) In the ALOFT system configuration, fiber optic bundles replaced conventional copper wires as a means of transmitting signals between the A-7 aircraft tactical computer and various components of the Navigation and Weapons Delivery System (NWDS).

(U) The flight test and evaluation of the ALOFT system at the Naval Weapons Center (NWC), China Lake, CA, was the first demonstration of the feasibility of using fiber optic technology in a full system application in an operational environment. Qualitative analysis of the test program results indicated that the performance of the ALOFT-configured A-7 aircraft was comparable to that of a fleet-configured A-7 aircraft in both navigation and weapons delivery modes.

(U) The ALOFT program was conducted at NWC under the sponsorship of the Naval Engineering Laboratory Center, San Diego, CA.

CONTENTS

A-7 ALOFT DEMONSTRATION

INTRODUCTION

In January 1973, the Naval Electronics Laboratory Center (NELC), San Diego, CA, entered into a contract with the Federal Systems Division of International Business Machines (IBM) Corporation under Contract No. N00123-76-C-1665 for the design, fabrication, and laboratory testing of a high-speed, multiplex fiber optic data link to interconnect the tactical computer and the head-up display (HUD) from an A-7 aircraft. The tests were made on the link between the TC-2 tactical computer and the HUD, and took the form of performance comparisons between the fiber optic link and the original conventional shielded-wire cable, as well as experiments on special properties of the fiber optical link. The results were conclusive: in a noise-free (no electromagnetic interference) environment, there was no detectable difference in performance between the two types of interfaces; in the presence of an electrical noise generator, however, the output display was unaffected when the signal was received via the optical channel, but it incurred serious deterioration when the shielded wires were used. These test results were the first quantitative validation that fiber optics were definitely immune to radio frequency interference (RFI), and electromagnetic interference (EMI).

The results of the IBM tests were made known to program review officers in the Navy Department and the Department of Defense. It was resolved that there existed a need to further investigate fiber optic data transmission in the form of a major feasibility demonstration to design and implement fiber optic links at a full-scale system level for test and evaluation. At this time, NELC proposed to the Commander, Naval Air Systems Command (NAVAIR) a 2-year program to install fiber optics in place of standard twisted-pair and coaxial cabling in the navigation and weapons delivery system (NWDS) of an A-7 aircraft to make demonstration and evaluation tests.

The proposal culminated in approval by the Assistant Secretary of the Navy for Research and Development for the implementation of the A-7 airborne light optical fiber technology (ALOFT) demonstration. This project was funded in March 1974 under AirTask A360360G/003C/4W41X1-001. NELC was designated to assume lead responsibility of the fiber optic development program.

NELC consolidated plans and objectives into a formalized development approach. The project was to consist of a 2-year program of which the major project phases are listed below:

1. A 6-month system analysis and design effort to design the system and to provide a system installation plan.

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2. A 6-month contractual effort to fabricate and check out the demonstration system in the contractor's laboratory.

3. A 3-month test and evaluation program of the demonstration system while installed in an A-7 ground simulator.

4. An 8-month test and evaluation phase of the demonstration system including aircraft modification, ground check, and flight tests of an A-7 test aircraft with the ALOFT system installed.

5. An economic analysis to analyze the comparative cost and performance benefits of the fiber optic system versus a wire interface system.

CONCLUSIONS

This report is concerned primarily with the third and fourth items listed above, which led to the following conclusions summarized here (and in greater detail in the Results and Comments section on p. 53).

The flight testing and evaluation of a fiber optics system was the first demonstration of the feasibility of using fiber optics in a full system application in an operational environment, in which fiber optic performed as well as a well-groomed fleet aircraft.

Normal aircraft moding was unaffected by the hardware and software modifications required in the aircraft, or by the use of fiber optics.

No adverse effects resulted from transmission of data by fiber optics for navigational update, backup mode bombing, bombing in sticks with various weapons, or firing guns and rockets.

BACKGROUND

In order to appreciate the scope of the project, it is necessary to examine both the fiber optics technology and the subsystems of the aircraft to which it was applied.

Fiber Optics Technology

The significant improvement of the electronic component technology in the last 10 years has fostered the fabrication of both more compact and more complex electronic systems. The applicability of this electronics product development capability was immediately recognized by the military consumer and prompted a demand for many highly complex computer-oriented systems. The improved performance provided by these new systems

is characterized by an increase in the data processing rates and in the quantity of data transmitted. The A-7E light attack aircraft is an early example of such a system. During the A-7E program development it was obvious that, because of system complexity and data rate requirements, improvements in system interfacing techniques would be required. Within the A-7E program, the constraints of wire data transmission lines were considered. Based on the operational capability of copper wire in the complex electronic system's electromagnetic environment, the interfaces that evolved were a differentially driven coaxial cable transmission line operating at a rate of 1 MHz and a twisted shielded pair operating at 50 kHz.

It is easy to project higher data transmission rates with the continuing growth of these complex systems and along with this increased proliferation of electronics, it will be necessary to contend with a more stringent electromagnetic environment. Additionally, the requirements of the environments of signal radiation due to nuclear weapons must be considered.

The study conducted by IBM concluded that using fiber optics for data transmission solved the problems of bandwidth limitations, EMI, signal radiation, and electromagnetic pulse (EMP).

Engineers at NELC summarized the important properties of fiber optic waveguides for the transfer of military information as follows:

1. Cross talk immunity between fibers and fiber cables.

2. Security from signal leakage and tap-in attempts.

3. No electrical grounding problems.

4. No dynamic loading, allowing connect/disconnect with system power on.

5. No short circuits which could damage terminal equipment.

6. Large bandwidth for size and weight. The increase in bandwidth, coupled with cross talk/noise immunity, makes multiplexing at high data rates possible.

7. Small size, lightweight (glass is one-sixth the weight of copper), and flexibility; thus, ease of installation.

8. Potential low cost. The strategic availability and high cost of copper as compared to glass will play a future role.

9. High temperature tolerance (500 to 1,000°C).

10. Safety in combustible areas and hazardous cargo areas (i.e., ammunition and fuel storage areas).

11. EMP immunity.

12. RF/EMI noise immunity.

The basic purpose of a data communications system is to transfer information. In a copper wire system it is the electron that carries the data; in a fiber optic system, it is the photon. The photon is not affected by electromagnetic fields; thus, the fiber optic cable has complete electromagnetic compatibility. The physics of basic electrical theory requires that copper conductors have a return in order to complete the circuit. The photon in a fiber optic travels down the fiber in waveform and there is no requirement for a return path, thus achieving ground reference level isolation.

A fiber optic system is composed of a light source, a medium for the light to travel through, and a light detector. Figure 1 illustrates a typical fiber optical data transfer system.

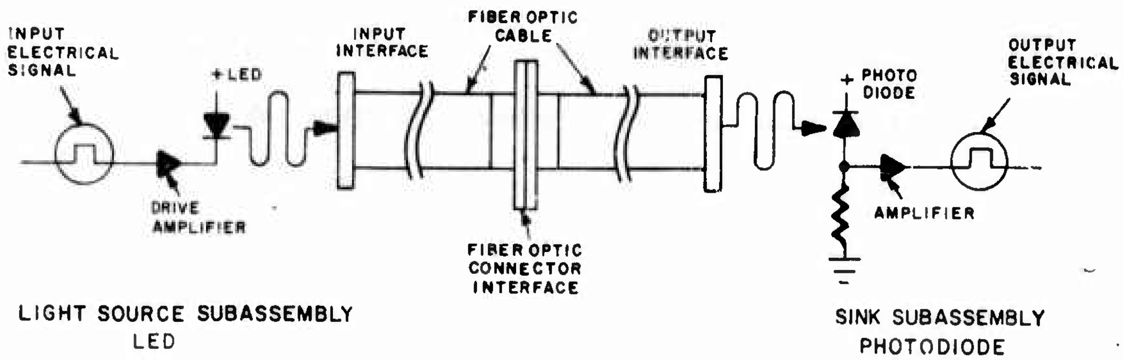


FIGURE 1. Components in a Fiber Optic Data Transfer System.

To convert from electrical to optical signals, a typical optic system uses a light-emitting diode (LED), which emits light in the near infrared region of the spectrum.

Glass or plastic fibers are utilized to transfer the light energy from the LED to a receiver device. Usually these fibers are contained in a bundle in order to provide a sufficient amount of light even if some of the individual fibers are broken or damaged.

To convert the optical signal back to electrical, a solid-state device called a photodiode is used. The typical photodiode detects light in the range from the visible through the near infrared.

Since most optical systems contain a number of subsystem elements, an optical connector must also become part of the system and serve to transfer the photons from one fiber group to another.

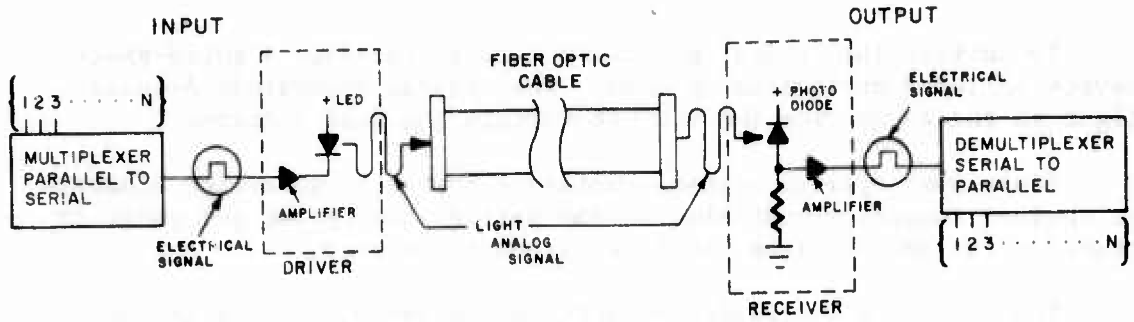
The following discussion of attenuation and modulation is necessary for a greater understanding of multiplexed fiber optic systems.

Light is attenuated as it moves down an optical fiber. Light is lost both to absorption and to scattering in the fiber. The absorption is determined primarily by the bulk of the glass from which the fiber is made. Radiation losses can also occur because of bends in the fiber, but losses are not significant unless bends are below a minimum bending radius.

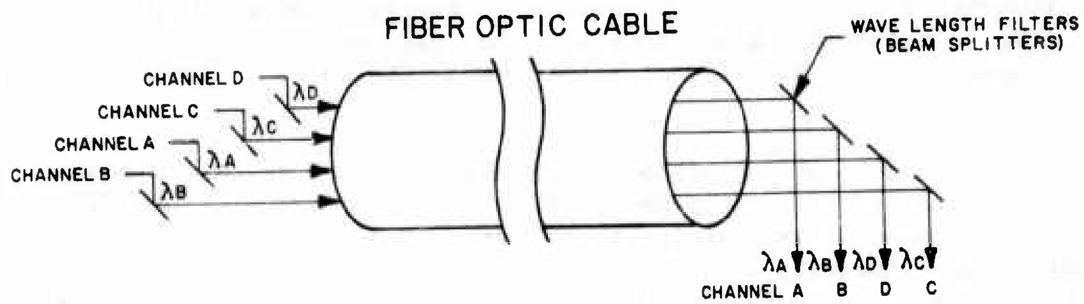
Light, as a carrier signal, from a source such as an LED must be modulated in order to carry data. Digital transmission is the easiest modulation mode to implement with otpics. This results from the approximate linearity of LEDs in which the light output varies directly with the drive current. The digital signal can be connected to the LED's input port through a driver circuit or by digitally controlling the bias current to the LED. This technique causes a logic 1 input to give a logic 1 light output. When using LEDs with fiber optics, modulation rates up to 200 MHz are possible for a 300-meter length at a loss factor of 50 dB/km. As future electronic systems evolve, greater speeds and larger memories will be included in the design. In order to interface these new systems, a faster, more efficient data transfer method must be available. Fiber optics is the most likely such candidate on the horizon because of its wide bandwidth. The only limiting factor at the present time is the LED technology.

A basic data transmission method easily applicable to fiber optics is multiplexing, a well-known technique that provides efficient use of a transmission medium. A large number of single-strand wires may be replaced by a single twisted pair for transmitting information or, similarly, a single fiber optic cable may replace many single-strand wires or single-strand fiber cables. In short, multiplexing is the process of combining several information channels and transmitting them over a single communications link.

The optimum multiplexing approach is known as "data bus" in which a central control computer addresses in turn each of the several remote units on a programmed basis in the time division multiplex (TDM) approach or, by addressing remote units individually, by suitable filtering in frequency division multiplexing (FDM). Figure 2 illustrates these two popular multiplexing methodologies. Figure 3 illustrates typical aircraft data bus architecture.



(a) Time division multiplexing.



(b) Frequency division multiplexing.

FIGURE 2. Multiplexing Methods.

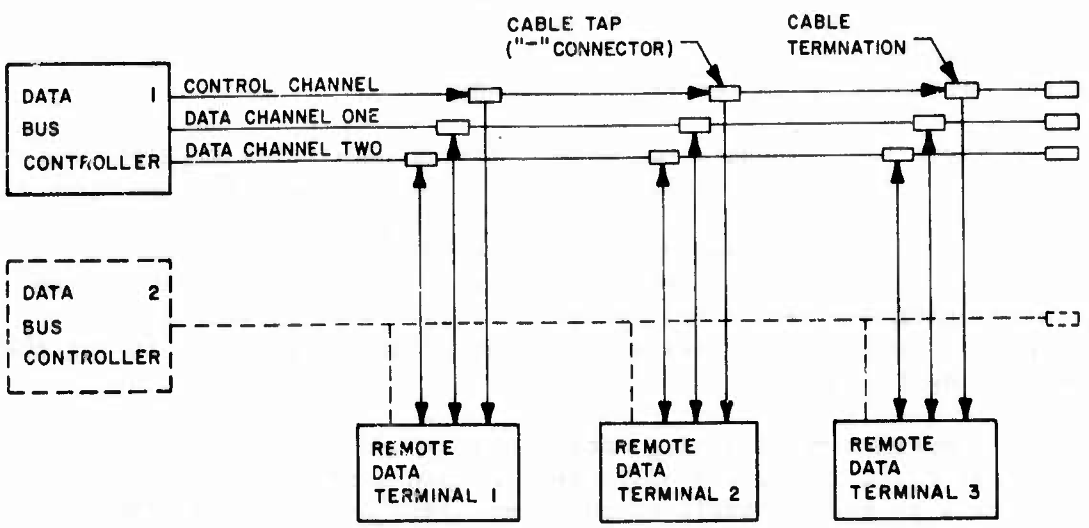


FIGURE 3. Typical Data Bus Architecture.

A-7E Light Attack Aircraft

The A-7E aircraft is a highly sophisticated attack aircraft capable of precision navigation and weapon delivery while operating in a hostile environment. Equipped with advanced sensors and computing devices, the A-7E represents a major deterrent force of the modern United States Navy.

The NWDS is the unique factor that makes the A-7E an advanced weapon in the Fleet's arsenal. The NWDS performs vital computations for increased delivery accuracy and for maneuvering freedom through the following phases: navigation to the target area, attack, weapon release, pullup, and a safe return to base. The NWDS provides the pilot with a number of options during navigation and weapons delivery and relieves him of much of his work load.

The intent of this presentation of the A-7 system is not to provide a detailed analysis of the system components, but merely to offer the reader a background of the unique capabilities inherent in the A-7, thereby making this presentation of the ALOFT goals more meaningful. Figure 4 depicts the location of the following seven avionics subsystems on an A-7 aircraft.

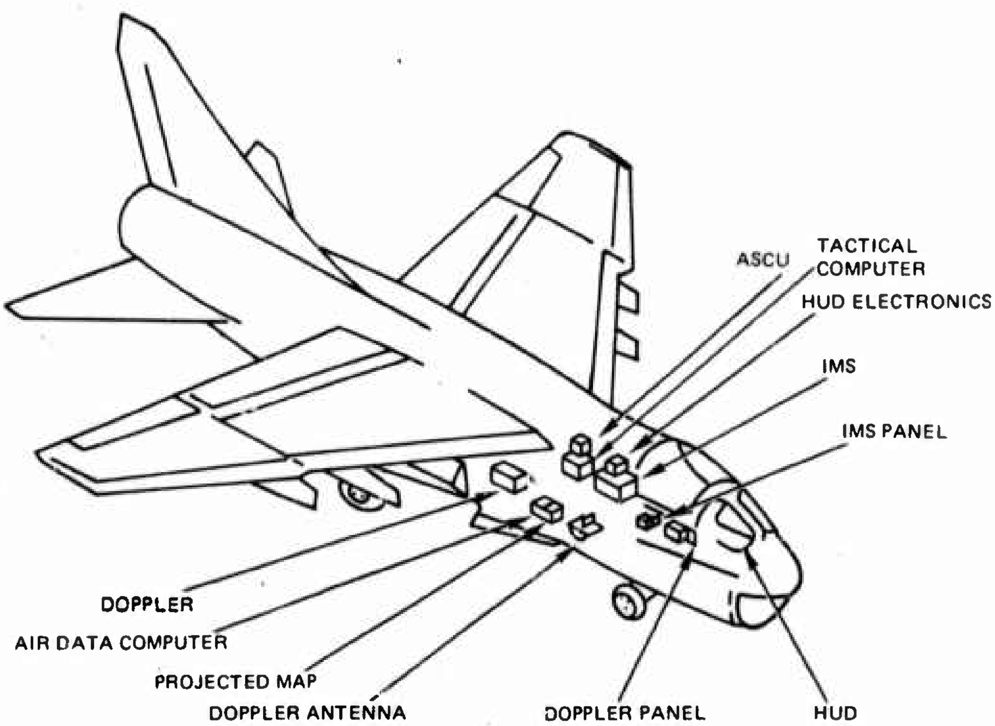


FIGURE 4. Orientation of Avionics Components.

1. The TC-2 Tactical Computer, AN/ASN-91(V) (navigation/weapon delivery computer (NWDC), is the primary element in the accuracy of the weapon delivery and navigation functions of the A-7. The NWDC communicates continuously with the basic avionic sensor systems of the aircraft. From this communication, it computes and displays present positions. The computer continually uses both computed and stored data to calculate navigation and weapons delivery solutions. It also monitors the reliability of data inputs and outputs from itself and from other avionic sensors throughout the aircraft. The computer has an integrated navigation and weapon delivery control panel (NAV panel) through which the pilot can "talk" with the computer by means of a keyboard. By this interface the pilot can, after initial entry of present location: enter nine pairs of coordinates as targets or destinations; accept and store the coordinates of nine more points of interest (possible targets) as he flies over them; and perform "flyover updates" where the computer will automatically display any difference between computed and actual present position. The pilot can then accept the correct position via the keyboard.

If a prime avionics sensor or system being monitored by the NWDS computer fails, the computer can cause the system to automatically revert to a backup mode, thus assuring the best available solutions to navigation or weapon delivery. The computer translates sensor inputs into fly-to-guidance commands on the HUD allowing the pilot to navigate with great ease and accuracy over considerable distance. In the target area the computer: issues HUD steering signals for guidance to the proper release point; continuously computes weapon trajectory (using stored ballistic information); and issues the weapon release signal for optimum release of the selected weapon.

2. The Inertial Measurement Set (IMS), AN/ASN-90(V), is the basic three-axis reference system for navigation and weapons delivery functions. The purpose of this unit is to sense rotations in the aircraft roll, pitch, and heading axes, and velocity changes in the north, east, and vertical directions. This unit is under tactical computer control and is capable of being positioned to true north and leveled to extreme accuracy on the ground or in flight. During flight, the computer constantly compares signals received from the IMS unit and those received from the doppler radar. From these inputs, the computer then computes the proper torquing signals required to maintain the inertial platform properly oriented with respect to the earth. The IMS system has two backup modes in case the computer is unreliable; if the IMS tests are unreliable, the navigation system will automatically assume a doppler radar/air mass dead-reckoning mode.

3. The Doppler Radar System, AN/APN-190(V), uses the doppler effect to continuously measure ground speed and drift angle with a high degree of accuracy and with complete independence of ground navigation aids. Information from a pitch- and roll-stabilized antenna is provided in analog form to the cockpit doppler panel for display of ground speed in knots and drift angle in degrees.

4. The Forward-Looking Radar (FLR), AN/APQ-126(V), provides the pilot with 10 modes of operation: (1) air-to-ground ranging (AGR), (2) terrain following, (3) terrain avoidance, (4) ground mapping (shaped beam), (5) ground mapping (pencil beam), (6) beacon, (7) cross-scan terrain avoidance, (8) cross-scan ground map, (9) TV, and (10) Shrike improved display system (SIDS).

5. The Head-Up Display (HUD), AN/AVQ-7(V), is an electro/optic (E/O) instrument that presents, in symbolic form, essential aircraft performance information, and attack, navigation, or landing guidance on a single display. Computed attack, navigation, and landing data are presented to the pilot by means of a combiner glass positioned in front of the pilot. With the HUD, the pilot has most of the flight information right before his eyes while he also looks at the real world scene outside the aircraft.

6. The Armament Station Control Unit (ASCU) is the primary unit in the integration and control of the weapon release system. The ASCU accomplishes the following functions: arms and releases weapons, fires and controls the fuselage gun, and furnishes the tactical computer with store-type information.

7. The Projected Map Display Set (PMDS) is a navigational aid employing full color projection of standard aeronautical charts reproduced on 35-mm film and stored in the unit. The PMDS provides a continuous display of the aircraft's geographical position. In response to the computer, the PMDS moves the film to keep the aircraft's present position updated on the map.

The integration of the six subsystems with a sophisticated computer allows the pilot to attack from any direction, altitude, and at any speed, knowing that evasive action will not degrade the accuracy of the weapon delivery. Added to the aircraft's stability, large load capability, and rapid response time, the NWDS of the A-7 yields accuracy and flexibility never before attainable in a single-seat attack aircraft.

SCOPE OF A-7 ALOFT PROGRAM

In brief, the A-7 ALOFT project consisted of an extended ground- and flight-test demonstration of an A-7 NWDS in which the signal wiring was replaced with fiber optic data cable between the tactical computer and selected flight sensors and avionic systems. One hundred fifteen shielded, twisted-pair wires which interconnect the ASN-91(V) TC-2 tactical computer and nine remote avionic sensor systems were replaced by 13 fiber optic cables. This was accomplished by incorporating time division multiplexing and fiber optic interface circuits to interconnect the NWDS system. Figure 5 shows the fiber optic data link modification to the A-7 avionics system. Information transmitted on the fiber optic channel is multiplexed and encoded into non-return-to-zero Manchester

format. The encoded data modulates the current source for an LED which transforms the electrical signal into an optic analog that is transmitted via a fiber optic cable to a positive-intrinsic negative (PIN) photodiode where the optic analog signal is decoded and demultiplexed into an electrical signal.

In summation, the A-7 ALOFT demonstration utilizes state-of-the-art fiber optic technology to link a present-day avionic system of remote sensors, command and control equipments, and peripheral processors to a general-purpose tactical computer.

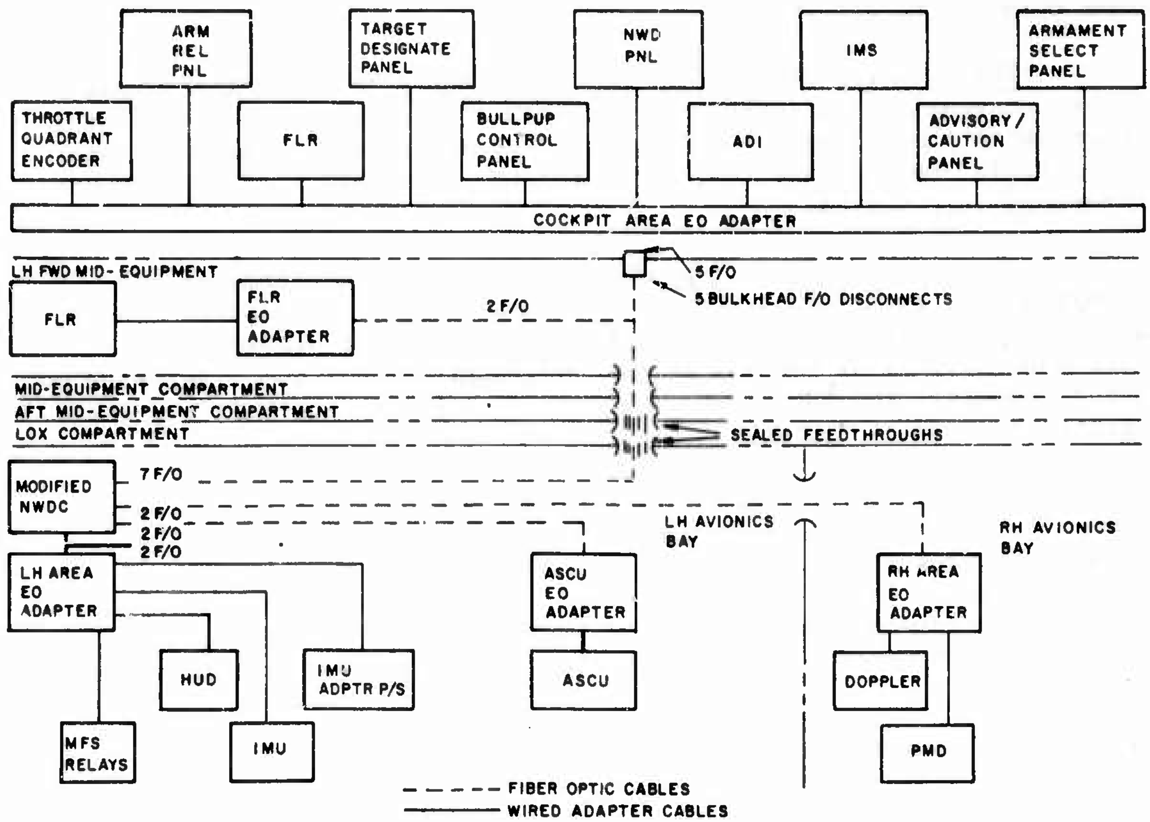


FIGURE 5. Fiber Optic Data Link Arrangement of the Modified A-7 Aircraft.

A-7 ALOFT SYSTEM TECHNICAL DESCRIPTION

The ALOFT system is made up of 13 fiber optic transmission lines, 12 digital links, and one analog link, which replace 115 electrical signals in the A-7. These signals comprise part or all of the electrical interface between the NWDS computer and 18 different electronic components used in navigation and weapons delivery functions aboard the aircraft.

The system diagram (Figure 6) depicts the total ALOFT system. As government-furnished equipment (GFE), an IBM TC-2 computer was assigned by the Navy to the ALOFT project. The TC-2 computer was modified internally to accommodate an E/O adapter. This adapter is shown in the diagram as the portion enclosed by dashed lines within the TC-2 computer. It contains the circuitry necessary to interface with the portions of the TC-2 input/output (I/O) being replaced by the ALOFT system to perform the appropriate multiplexing and demultiplexing, and to do the needed electrical signal to optical signal conversion. Space within the computer was made available by using a TC-2A high-density analog converter. Communication between the TC-2 adapter and the other five E/O adapters is done strictly through fiber optic cables, represented on the diagram by dashed arrows to/from the TC-2 adapter.

The information above the arrows gives the type and quantity of signals being transmitted through that particular cable. In the case of the cockpit adapter, there are two nonmultiplexed channels. One is for the 1-MHz data line from the navigation and weapons delivery control panel to the TC-2, and the other for a direct analog optical link from the TC-2 to the attitude direction indicator. The solid arrows, to and from the E/O adapters and the A-7 electronic system assemblies, indicate the direction of data transmission and the number of electrical signals being transmitted and received by each adapter.

SIGNAL INTERFACES

Appendix A contains a more detailed description of the signal interfaces in the ALOFT system, including an explanation of the multiplexing schemes, Manchester encoding, and the E/O circuits.

In designing the electrical interfaces for the ALOFT system, care was taken to maintain the adapter-to-electronic-assembly interfaces identical to the previous computer interface. The adapter inputs and outputs have the same electrical characteristics, impedance, threshold, etc., as those in the original Fleet system.

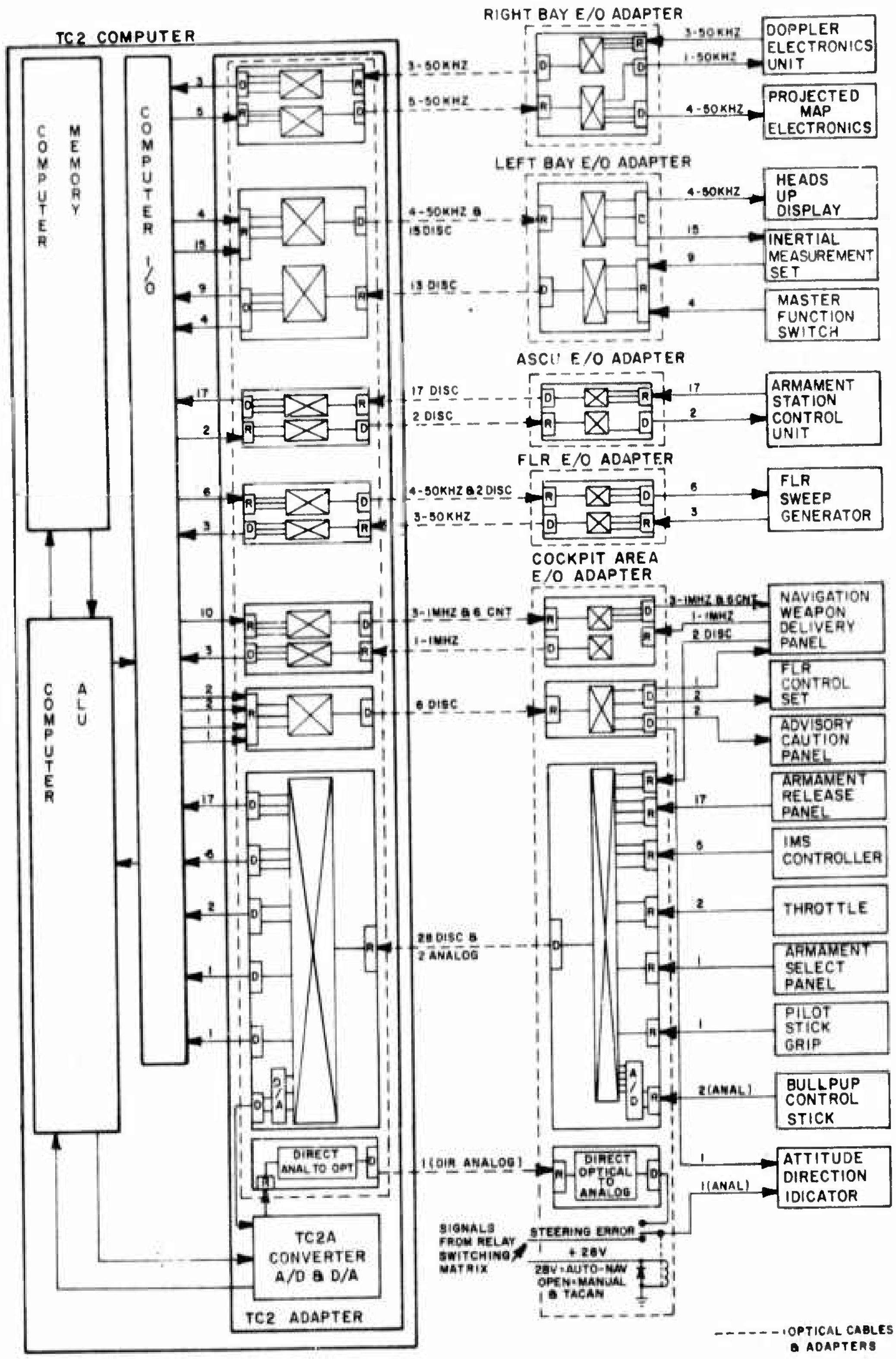


FIGURE 6. ALOFT System Diagram.

The ALOFT system interfaces with the following signal types:

1-MHz digital signals

50-kHz digital signals

Digital pulse trains

Digital discretes, +5 and +28 VDC

Switch closure signals

Analog signals (two ±4 VDC (Bullpup) and one ±2 VDC attitude direction indicator (ADI)).

(Table E-1* (p. 93) lists signals, formerly transmitted by wires that, in the ALOFT system are transmitted through the fiber optic cable to each adapter. Table E-2* (p. 102) repeats those signals of Table E-1 that are multiplexed and gives their adapter designation and pin numbers: signal name and type, computer I/O pin designations, driver or receiver circuit type, adapter I/O pin designations, and A-7 electronic assembly pin designations.)

In order to facilitate the testing and maintenance of the ALOFT computer (with the TC-2A signal converter) using existing test facilities, the computer was designed with a convertible feature. This consists of the configuration capability of ALOFT/COPPER, which is a conventional wire mode data interface, and ALOFT/FIBER OPTICS, which is a fiber optic data interface. When the computer is in its "wired mode" configuration, it presents the same I/O to the aircraft avionics as it did prior to modifications.

The conversion from COPPER to FIBER OPTICS provides the means to establish a reference for the performance of the ALOFT fiber optic hardware.

Figure 7 shows an exploded view of the ALOFT computer.

*See Appendix E.

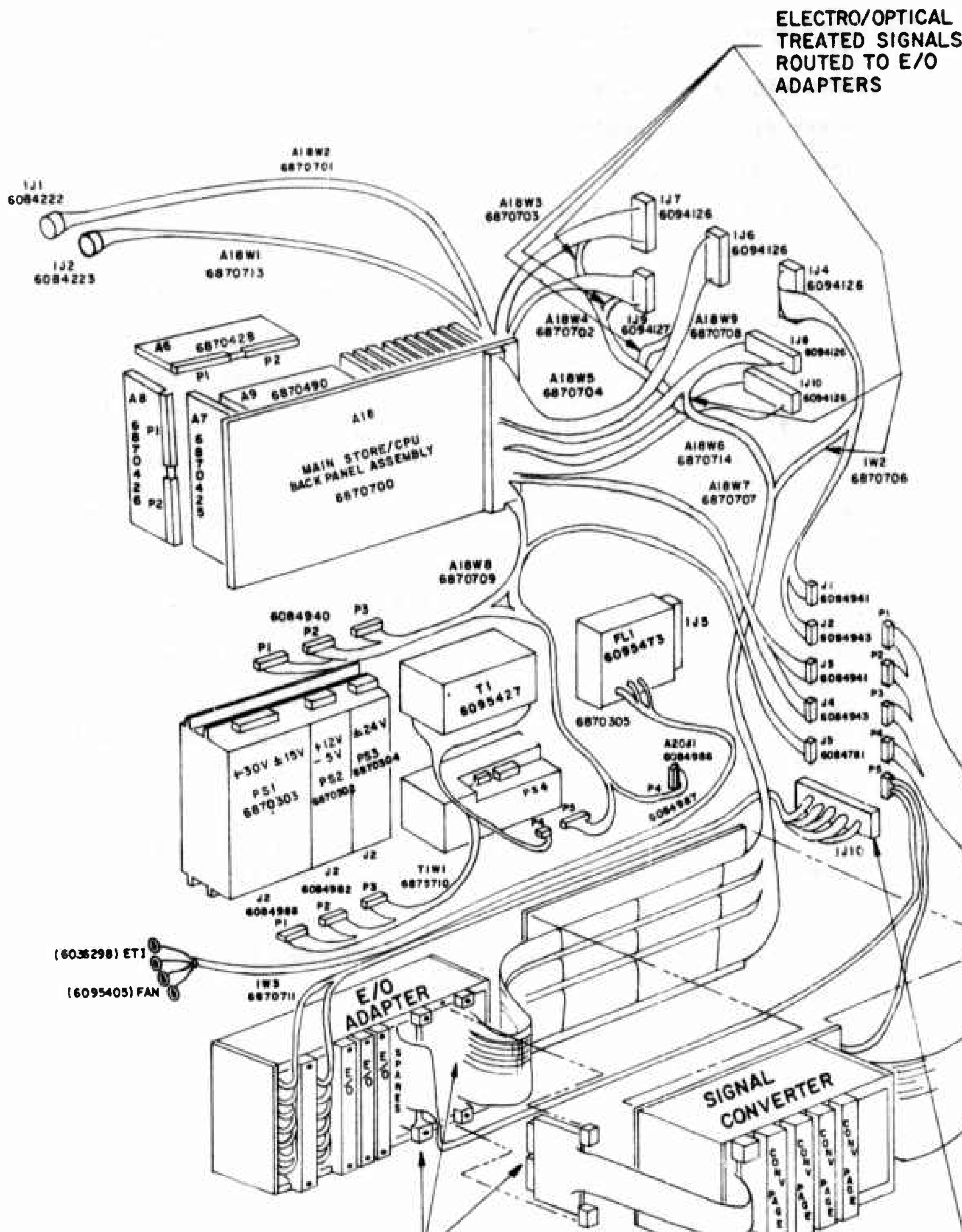


FIGURE 7. Exploded View of the ALOFT Computer.

ALOFT MODIFICATION INSTALLATION

BACKGROUND

Prior to describing the modification effort on the A-7 aircraft, some of the reasons for selecting the A-7 as the test aircraft are discussed.

The primary reason the test role was assigned to the A-7 aircraft is the fact that the A-7 has an avionics system that is compatible with the test objectives of the ALOFT program. Access to all areas concerned with the installation of the ALOFT equipments is available on the A-7, and several A-7 simulators are available for accomplishing the prevalidation integration and installation phase of the ALOFT program.

EQUIPMENT INSTALLATION

In order to integrate the ALOFT system into the A-7 aircraft, changes to the aircraft structure and wiring were required. To minimize these changes, some ALOFT cables were made longer than the wiring harnesses they were to replace. This allows existing accesses to be used, markedly reducing the number of structural changes required. In order to eliminate the need for splicing and to facilitate the use of existing connectors, "T" cables were used as an integral part of the design logic.

Vought Systems Division of the Vought Corp., Dallas, TX, under contract to the NELC, designed the installation plan. This effort included environmental analysis, wiring, and mechanical design. The hardware necessary to perform the modification was supplied to the Naval Weapons Center (NWC), China Lake, CA, by LTV/NELC in the form of an installation kit. Installation of the fiber optic components was the responsibility of IBM/NELC.

The ALOFT modification was installed in A-7C aircraft, BuNo. 156782. The modification required sheet metal work in three areas: (1) drilling a hole in the bulkhead between the liquid oxygen compartment and the left avionics compartment, (2) the installation of a pressurized bulkhead fitting with six feedthroughs in the cockpit section, and (3) the mounting of five ALOFT adapters in the left and right avionics equipment compartments, in the sweep generator compartment, and in the cockpit. Figure 8 is a photograph of the ALOFT computer and peripheral E/O adapters. Appendix B gives a detailed installation description.

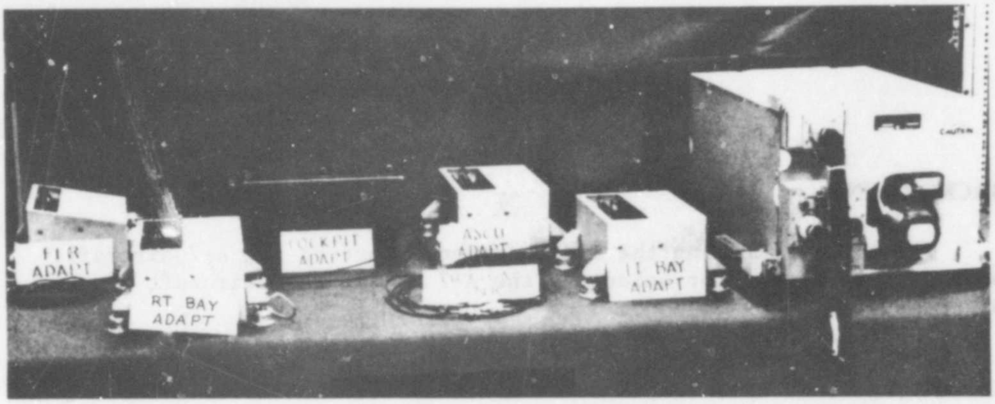
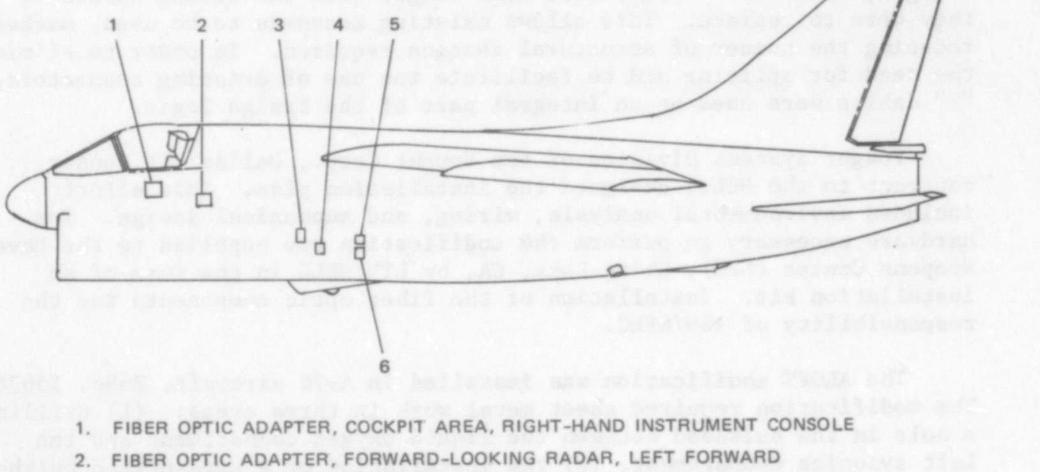


FIGURE 8. ALOFT Computer and Peripheral E/O Area Adapters.

Six wiring harnesses were installed, one in each of the compartments mentioned above, to connect the area adapters to the avionic components in those areas. Figure 9 shows the relative location of the area adapters.



1. FIBER OPTIC ADAPTER, COCKPIT AREA, RIGHT-HAND INSTRUMENT CONSOLE
2. FIBER OPTIC ADAPTER, FORWARD-LOOKING RADAR, LEFT FORWARD MID-EQUIPMENT COMPARTMENT
3. FIBER OPTIC ADAPTER, LEFT AVIONICS COMPARTMENT, FUSELAGE STATION 358
4. FIBER OPTIC ADAPTER, RIGHT AVIONICS COMPARTMENT, FUSELAGE STATION 371
5. FIBER OPTIC ADAPTER, ARMAMENT STATION CONTROL UNIT, LEFT AVIONICS COMPARTMENT
6. FIBER OPTIC INSTRUMENTATION PACKAGE, RIGHT AVIONICS COMPARTMENT

FIGURE 9. Location of Area Adapters.

ALOFT PROGRAM

In the conduct of the ALOFT Program, NELC was the lead activity, directing the work portions being done by IBM; LTV; Naval Air Test Center (NATC), Patuxent River; and NWC. The major assignment to NWC was to conduct the demonstration flights of ALOFT/FIBER OPTICS. Before demonstration flights could be made, other preparatory tasks (also assigned to NWC) involved modification tests of the operational flight program/operational test program (OFP/OTP), modification of computing, and cabling an A-7C aircraft in such a way and on such a schedule that it could be flight-tested in three configurations. These tasks and the plans for carrying them out are contained in the flight test plan prepared by and implemented at NWC in cooperation with all the participants. Detailed requirements are also contained in Appendix C (tables are referenced simply by number both in the discussions of the flight test plans and of the ground and flight tests).

FLIGHT TEST PLAN

The three-phase plan is stated in detail in the *A-7 ALOFT Demonstration Flight Test Plan*[1] whose major provisions are summarized here.

Phase I, Predemonstration Validation

The predemonstration validation is the primary method of determining the integrity of the aircraft system in the FLEET configuration before the modification and the baseline tests. After the ALOFT modification, this validation, except for boresighting, was repeated and a cursory validation made before the ALOFT/COPPER baseline tests. One test was repeated before the ALOFT/FIBER OPTICS baseline test. Table C-1 is a summary chart that shows the validations required for each configuration and indicates whether they are to be done in the laboratory or in the aircraft.

Phase II, Baseline Flights

Before any modifications were made, 10 baseline flights were flown in the FLEET configuration of the aircraft. Then, after the modification

[1] Naval Weapons Center. *A-7 ALOFT Demonstration Flight Test Plan*, by R. R. Bruckman and J. D. Ross. China Lake, Calif., NWC, September 1975. (NWC TN 404-216, publication UNCLASSIFIED.)

and reverification, 10 more flights, duplicating the conditions of the first 10 in the FLEET configuration, were repeated for the ALOFT/COPPER configuration of the aircraft.

In both cases, the first four flights were to test navigation functions as specified in Table C-2. These were followed by three weapons delivery flights, each with multiple passes, as shown in Table C-3, and three minimum release interval (MRI) weapons flights, as shown in Table C-4.

Phase III, ALOFT Demonstration Flights

At least 10 flights, essentially duplicating the conditions of the ALOFT/COPPER baseline flights, were made in the ALOFT/FIBER OPTICS configuration. Provision was also made in the plan to include a gun/rocket flight as shown in Table C-5 and, if possible, one flight with mines and flares and two environmental flights.

Records

Included in the plan were directions for recording data and for documenting separately any failures or malfunctions as being non-ALOFT as distinguished from ALOFT or ALOFT-related. Data analysis is discussed in a later section, and failures or malfunctions are discussed in Appendix D.

GROUND AND FLIGHT TESTS

Predemonstration Validation

The predemonstration validation was the primary method of determining aircraft integrity prior to performing the ALOFT demonstration. This validation included various checks to demonstrate that the aircraft could properly and safely fly. It consisted of a cursory validation, selected ground checks, and a series of grooming flights to verify system integrity.

In this program the A-7 was configured in three different ways: FLEET, where the A-7 is equipped with a standard computer utilizing the current fleet OFP; ALOFT/COPPER, where the A-7 is equipped with a modified computer and modified OFP; and ALOFT/FIBER OPTICS where the A-7 is equipped with the ALOFT/COPPER computer, further modified to use fiber optics in place of the wire interfaces for data transmission.

Details of the various checks and tests accomplished during the predemonstration validation are found in Appendix C.

Baseline Flights

The baseline flights, an identical series for each configuration of the aircraft, were flown to establish a data base by which valid comparison could be made among the three aircraft configurations. The FLEET configuration had a standard TC-2 computer and standard wiring between it and the avionics subsystems. The other two configurations had a TC-2 computer, but with modifications that included a TC-2A analog-to-digital converter. They differed from each other in that one configuration, ALOFT/COPPER, had copper wire interconnections with the avionics, while the other, ALOFT/FIBER OPTICS, had fiber optical cabling. (The ALOFT/FIBER OPTICS configuration was flown only in the demonstration flights.)

Navigation Mode Functions. To evaluate the navigation functions, the first four flights in each ALOFT series duplicated the conditions prescribed for flights with the FLEET configuration that were flown before any modifications were made. Each navigation flight was over a predetermined route with good visual and update points on B-Range, NWC. Each flight was approximately 2.5 hours in duration and each made wind and doppler checks at predetermined intervals in the various alignment and mode conditions shown in Table C-2. Data were taken by the flight recorder including: (1) navigation velocities and attitudes, and (2) present position error computed in arc seconds by a flyover update in which the computed error was compared to known coordinates to check the accuracy of the sensors in the particular mode being flown. In the prime navigation mode, the following combinations of updating and ranging used were: (1) HUD with FLR, barometric altimeter (BARO), and radar altimeter (RAD ALT); and (2) radar with BARO and RAD ALT. Wind data were taken on each flight by flying a box pattern at constant altitude, and recording wind velocity and bearing at each cardinal heading.

Weapons Delivery. Seven flights, each with multiple passes, were flown as shown in the matrices of Tables C-3 and C-4. Their results are included in the Data Analysis section.

Minimum Release Interval (MRI) Flights. In addition to the conventional weapons delivery flights, MRI evaluation flights were made to test the accuracy of the computations and the moding of the MRI equations. The flights were structured to test each MRI class for accuracy of the MRI computations at different values of normal acceleration. The moding was checked to verify that the OFP selected the proper MRI class according to the armament station control unit (ASCU) code, the retard switch for pilot option weapons, the number of stations selected, and the quantity thumbwheel setting, for conditions affecting automatic reversion to the Class II (safe MRI) feature. Table C-4 shows the MRI evaluation flights in the form of the MRI weapon flights matrix. The flights were evaluated by noting the interval and pulse width of the recorded fire release pulses

recorded fire release pulses from the computer and comparing this interval with the MRI equation for the value of normal acceleration recorded at release. The interval between the fire release pulses was programmed with no discernible error.

Demonstration Flights

The demonstration flights with the ALOFT/FIBER OPTICS configured aircraft were designed to repeat the conditions of the baseline flights, as nearly as possible, for the first 10 flights (Tables C-3 and C-4). An eleventh flight with rockets and the M-61 gun was added.

The data and their analysis, discussed in a later section, were divided into six categories as follows: (1) and (2) bombing accuracy in the prime and in the backup modes, (3) miscellaneous bombing, (4) guns and rockets, (5) navigational update, and (6) wind correction.

TESTS OF ELECTROMAGNETIC INTERFERENCE, LIGHTNING, AND RELIABILITY AND MAINTAINABILITY

The electromagnetic interference susceptibility tests were conducted by McDonnell Aircraft Co. under Contract N00123-76-C-0324 as an add-on task. The objective of this test was to provide a comparison of the EMI susceptibility of the test aircraft's fiber optic modified computer and navigation and weapons delivery system with the unmodified conventional wire system. The simulated lightning tests were performed by the Electro Magnetic Hazards Group, Vehicle Equipment Division, Wright-Patterson Air Force Base, Ohio. The primary objective of the test was to make a quantitative determination of the reduction in lightning transient susceptibility of the navigation and weapons delivery system of the A-7 aircraft in a FIBER OPTICS configuration.

EMI TEST STRATEGY

The EMI susceptibility test on the aircraft was conducted by coupling noise onto the copper wire (twisted shielded pairs) cables between the electronics (avionic subsystem) and the electro-optical area adapters. Because of the A-7's double shielding, it was decided that a comparative test would be to lift one end of the overbraid and connect the transient generator between the shield and the aircraft structure. The overbraid, therefore, became the test wire carrying the induced noise. This resulted in a sufficient amount of noise being coupled into the system so as to be seen as interference on the cockpit instruments. The noise was also coupled to the fiber optic lines. Figure 10 shows the general arrangement of the test setup.

Results and Conclusions

The results of the test showed that, when 200-volt spikes were introduced on the test wire coupled to the fiber optic bundles, no evidence of degraded operation of the HUD or PMDS cockpit display was evident. However, 110-volt pulses on the HUD test shield adjacent to the copper wire resulted in severe distortion of the HUD display. The PMDS display suffered distortion and interference with only 45-volt spikes from the generator.

It was then concluded that this test demonstrates the invulnerability of a fiber optic data-transfer medium to EMI levels commonly found in aircraft. Noise levels that caused malfunctions in conventionally wired avionics did not disrupt the fiber optic system.

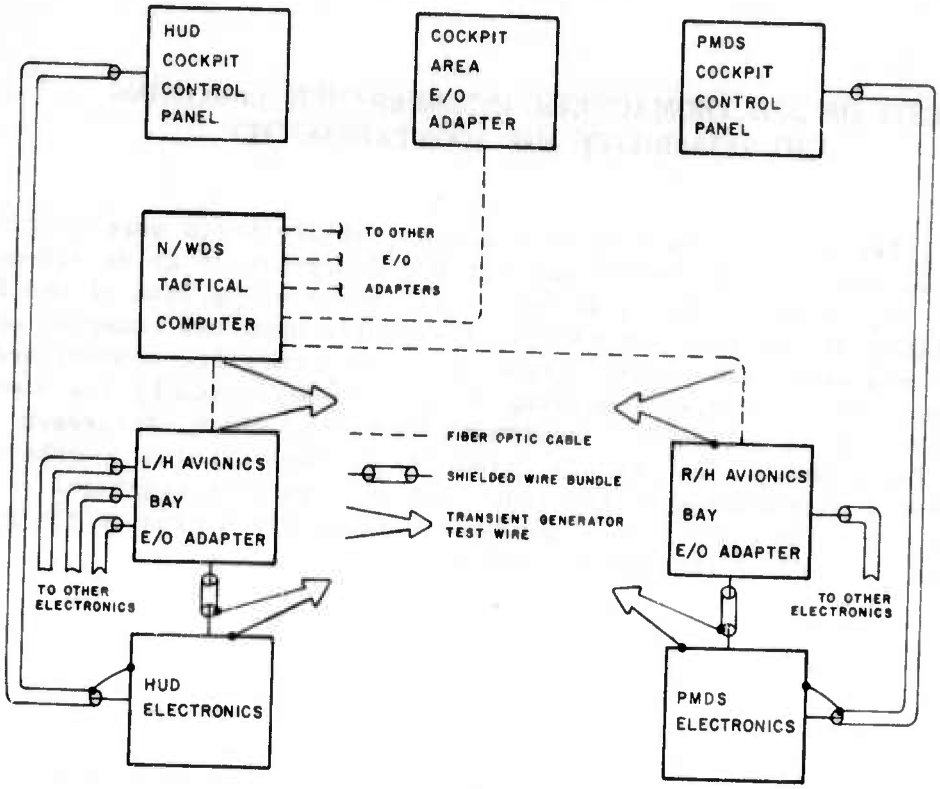


FIGURE 10. EMI Test Setup on ALOFT Aircraft.

SIMULATED LIGHTNING TEST STRATEGY

A 2,000-ampere peak current pulse was applied to the aircraft to simulate the lightning current. The shape of this pulse approximated that of lightning, but its amplitude was much lower. The induced transient measurements were made within the computer at the central processing unit (CPU) interface. The induced voltages observed were analyzed with respect to time domain, peak amplitude, and duration. The 2,000-ampere peak current pulse of double-exponential wave shape had a 2-μsec rise time and approximately 50-μsec decay time. This pulse was generated by a triggered bank of capacitors charged with voltage between 25,000 and 200,000 volts into wires connected to the aircraft via attachments to the structure at the vertical fin and near the pitot static tube. Figure 11 shows the lightning test setup which allowed the simulation of typical lightning current flow through the aircraft from nose to tail. During a 2,000-ampere simulated lightning test, it is possible that arcing may occur. Therefore, before conducting the test, it was necessary to inert the fuel system of the aircraft; this was accomplished by pumping nitrogen into the fuel tanks and lines.

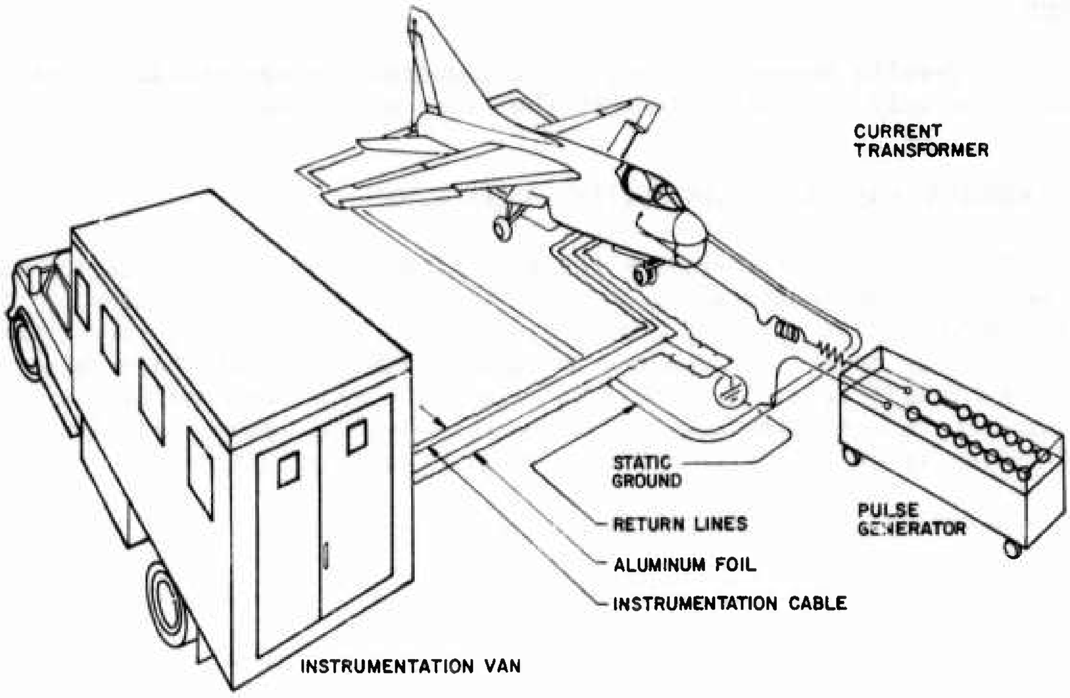


FIGURE 11. Lightning Test Setup.

The measurements of induced voltage were made on specific data channels within the computer. For this purpose, shielded-wire connections were made from spare pins on existing connectors on the TC-2 to the various required circuit points within the CPU. Seven data channels were chosen for investigation: four transmitting channels, HUD, FLR, PMDS, and NAV PANEL; and three receiving channels, DOPPLER, FLR, and NAV PANEL. All measurements were made at the CPU itself for maximum generality. The test was conducted on the aircraft in the configurations and modes as outlined in Table 1.

TABLE 1. Aircraft Test Configurations.

Configuration	Cabling		
	Power	Hard-wired signal	Fiber optic
A	ON	OFF	ON
B	OFF	OFF	ON
C	OFF	ON	OFF
D	ON	ON	OFF

Results

The results showed a 300-mV spike inducted through standard aircraft wiring and only a 30-mV spike when the fiber optics were used.

RELIABILITY AND MAINTAINABILITY EVALUATION

The purpose of reliability and maintainability (R&M) evaluation was to determine the quantitative and qualitative R&M characteristics of the A-7 ALOFT-modified aircraft during operational use including identification of those areas that degrade or enhance R&M. The data base expected from the flight test phase would be relatively small and technically inadequate to establish meaningful quantitative R&M characteristics; therefore, it was more important to obtain qualitative R&M.

The scope of the R&M evaluation included:

1. Determination of ALOFT component and system R&M characteristics.

2. Evaluation of the adequacy of the proposed maintenance concept, level of repair, and other supportability parameters applicable to the installation.

3. Evaluation of fault detection and isolation provisions and capabilities, including tradeoffs for peculiar ground support equipment (PGSE), built-in test (BIT), and troubleshooting.

4. Determination of skill levels and training requirements applicable to fleet maintenance.

5. Evaluation of accessibility for visual and manipulative tasks, interchangeability, safety, weight, and labeling of assemblies and components.

6. Determination of the PGSE or facilities required to maintain the ALOFT system.

A total of 45 flights (72.1 flight hours) were accumulated with no limitations on system operation. Navigation and weapons delivery accuracy flights were conducted to compare the ALOFT system performance against a previously established baseline performance of the copper-wired system. Although flying has been extended indefinitely to accumulate additional performance data, the lack of additional funding and timely completion of a final report required establishment of an early R&M data cutoff date.

The A-7 ALOFT aircraft's common NWDS weapon replaceable assemblies (WRAs) were maintained by NWC. The ALOFT-peculiar WRAs were maintained by IBM personnel. A quantitative and qualitative evaluation of the installation was conducted by NATC during a 2-week period at the beginning of the flight test program. Following this evaluation, during periodic visits to NWC, maintenance was monitored, repair documentation verified, and selected maintenance and flight data were gathered.

Results and Discussion

The ALOFT demonstration was conducted to confirm that fiber optic technology is mature and practical for use in internal aircraft data signal transmission. The flight tests and evaluation of the system were the first demonstrations of the feasibility of using fiber optics in a full system application in an operational environment. Previous demonstrations of this technology in the United States were limited to laboratory level or small-scale flight evaluations at the subsystem level.

There were no requirements to demonstrate specific levels of R&M. The goal was to demonstrate that the test aircraft operated exactly like its fleet counterpart. Military standards and specifications for airborne equipments were complied with specifically in the areas of flight safety and environmental compatibility. There are no military standards or specifications that address airborne fiber optic technology although some are in development.

The ALOFT WRA lacked some design and manufacturing considerations applicable to production hardware such as reference designators, wire routing and attachment, and environmental encapsulation. The ALOFT system imposed no internal design impact on A-7 avionics other than the NWDS tactical computer.

A production fiber optic installation would incorporate input/output electro-optical conversion devices in place of the normal electronic line drivers in avionics peripheral to the computer, thereby eliminating the requirement for adapter units. Additionally, the use of unique rack and panel connectors similar to the one developed for the ALOFT tactical computer would be used to eliminate the single fiber optic connectors used on the ALOFT adapters. Appendix D describes the method in which the R&M data were analyzed.

DATA REDUCTION PROGRAMS AND AIRCRAFT RANGE

PROGRAMS

There are three UNIVAC 1108 FORTRAN V computer programs to provide information to evaluate the accuracy of the A-7E weapon delivery system. These include: (1) the SCAN program which prints out the logical choices and the discrete input and output words from the onboard TC-2 tactical computer, (2) the LIST program which tabulates, in engineering units, the parameters utilized in the computer, and (3) the CORRELATION program which makes a comparison of these parameters with aircraft flight parameters obtained from Askania cameras or radar.

A pulse code modulated (PCM) tape is written by the onboard data recorder which is wired to the aircraft tactical computer. This tape is digitized by NODAC, and a FORTRAN tape is written that is used in the SCAN and LIST programs.

SCAN and LIST Programs

The SCAN program enables the analyst to make judgments as to the various phases of the equipment that were in operation during the pass and to determine the portion of the pass that is to be examined. The state of the logical and discrete words are printed out at the beginning of each pass. When one of these states changes, it is printed out along with the time of its occurrence. The LIST program prints out parameters in the order they are requested. The data can be printed at various time intervals with different sampling rates during a pass.

CORRELATION Program

The CORRELATION program compares the data utilized in the onboard tactical computer with measurements made on the range. The aircraft's position, velocity, azimuth, and flight path angles can be determined from this comparison. Using atmospheric data, the program can further refine the data by adding wind and pressure information. From these data, the mean error, standard deviation, and root mean square of the differences are computed. The output of this program consists of smoothed range data and delta values.

AIRCRAFT RANGE OF NWC

The aircraft ranges of the Naval Weapons Center are field laboratories for the development and testing of weapons and weapon systems. Weapon systems and associated ordnance are tested here to verify basic concepts, to prove the accuracy of development and production techniques, and to demonstrate effectiveness, operation, and reliability.

B-Range

Most of the A-7 ALOFT flights were flown against the large variety of targets and target areas available at B-Range. The use and selection of a target is directly related to the data or information desired. Scoring of impacts with respect to the targets is accomplished by triangulation from spotting towers that are provided for the most used targets.

An Askania cinetheodolite was used as the primary high-accuracy data source. In addition to the photographic data-recording instrumentation, B-Range utilized three types of radar systems for flight control and data gathering. These radars were interfaced to a PDP-7 and PDP-9 digital computer for real-time data readouts of azimuth, elevation, range, time, and velocity, on a line printer at the rate of 10 lines per second. All data gathered at the range were then reduced and analyzed to measure the accuracy of the weapon or weapon system.

DATA ANALYSIS

In order to determine whether the installation of the ALOFT fiber optics degraded the aircraft system performance, it was essential to isolate the effects of all parameters other than the fiber optics itself. The most significant parameters that could introduce spurious results were the changes in the computer and the computer software instituted for ALOFT. Because of the dramatic effect the software could have on results, a complete set of experimental flights were dedicated to removing any such effects. Thus, all data were separated into three partitions, FLEET, ALOFT/COPPER, and ALOFT/FIBER OPTICS.

Other sources of variability in the data included: equipment degradation, loss of boresight, pilot-to-pilot variability, aircraft-to-aircraft variability, measurement error, and tactics/modes of operation. Particular attention was paid to avoiding any such variation from contaminating the data.

In order for this report to be unclassified, it was necessary to normalize the data gathered during the bombing and navigation flights. This was accomplished by presenting the mean, median, and standard deviations scaled to X, where X is the accepted specified accuracy of the A-7 aircraft.

For purposes of discussion the data and analyses were divided into six categories and treated in the order listed as follows: bombing accuracy (prime modes), bombing accuracy (backup modes), miscellaneous bombing, guns and rockets, navigational update, and wind correction.

BOMBING ACCURACY (PRIME MODES)

Data

Considerable bomb drop data were taken in various bombing modes to verify that the weapon system accuracy was unaffected by ALOFT fiber optics and that all bombing modes could be selected as in a fleet-configured aircraft. The principal source of data on bombing accuracy comes from tests of four prime bombing tactics (normal attack with FLR or BARO ranging and straight-pass or dive-toss deliveries). Although BARO might not be an accurate bombing mode in actual fleet bombing, the carefully controlled conditions at NWC made BARO bombing, in general, equal or superior to bombing with radar ranging.

Tables 2, 3, and 4 list the miss distances for all bomb drops done in 45-degree dives in the four modes given above, for the FLEET, ALOFT/COPPER, and ALOFT/FIBER OPTICS configurations, respectively. Although successful drops were also made with 30-degree dives and manual ripple in each of these flights, these drops are not used in the bombing accuracy analysis.

TABLE 2. FLEET Configuration Bombing (Prime Modes).[a]

Flight	Pilot	Date	Ranging Attack: Straight path BARO	Straight path FLR	Dive-toss BARO	Dive-toss FLR	Mean	Median	Std. dev.
582-51-71A	Harrel	2/20/76	0.29 1.15	0.73 0.93	0.48 1.04	0.45 1.27	0.79	0.83	0.34
582-54-73	Duncan	2/23/76	0.82 0.36	0.85 0.51	0.53 0.76	0.93 0.15	0.61	0.65	0.25
582-49-69	Fleming	2/18/76	0.72 0.58	0.18 0.87 0.22			0.51	0.58	0.27
		Mean	0.65	0.61	0.70	0.70	0.66		
		Median	0.65	0.73	0.65	0.69		0.72	
		Std. dev.	0.29	0.22	0.43				0.31

[a] Scaled to X, the specified A-7 bombing accuracy.

Analysis

The means, medians, and standard deviations presented are segregated by pilot and attack mode. This partitioning of the data is intended to uncover any variations produced by these parameters so that, if present, their magnitude can be estimated. It can be seen by examining the means and medians of the FLEET data (Figure 12) that variation in bombing results due to the four modes is fairly minimal and in all cases significantly less than the standard deviation. This means that a composite statistical indicator of the entire FLEET configuration data is justified, as long as comparisons made using this indicator are not closer than about 0.1X mil. Furthermore, any portion of the data can be expected to represent the whole data base, again to about 0.1X mil.

TABLE 3. ALOFT/COPPER Configuration Bombing (Prime Modes).[a]

Ranging Attack									
Flight	Pilot	Date	Straight path		Dive-toss		Mean	Median	Std. dev.
			BARO	FLR	BARO	FLR			
582-72-85	Duncan	3/12/76	0.94	0.63	1.15	1.01			
			0.23		0.55	0.77	0.75	0.77	0.29
582-73-77/78	Harrel	3/13/76	1.55	1.13	1.59	1.29			
			0.22	1.41	1.06		1.15	1.29	0.41
	Fleming			0.75			0.75	0.75	0.0
		Mean	0.64	1.04	1.09	1.02	0.94		
		Median	0.59	1.05	1.11	1.01		1.01	
		Std. dev.	0.42	0.35	0.37	0.21			0.04

[a] Scaled to X, the specified A-7 bombing accuracy.

TABLE 4. ALOFT/FIBER OPTICS Configuration Bombing (Prime Modes).[a]

Ranging Attack									
Flight	Pilot	Date	Straight path		Dive-toss		Mean	Median	Std. dev.
			BARO	FLR	BARO	FLR			
582-112/104	Tkach	4/21/76	1.62	1.06	0.93	1.79			
			0.93	0.98	0.90	1.33	1.19	1.02	0.32
582-111-101A	Harrel	4/20/76	1.81	0.62	1.13	1.64			
			1.21	1.41	1.35	0.73	1.24	1.28	0.38
582-160-153A	Kaufman	6/8/76	0.89	1.39	1.16	1.31			
			0.12	1.73	0.70	0.28	0.95	1.03	0.52
582-161-158		6/9/76	0.50	1.15	0.94	0.52			
			0.86		0.38	0.38	0.64	0.52	0.23
		Mean	0.99	1.15	0.94	1.00	1.02		
		Median	0.91	1.06	0.94	1.02		0.94	
		Std. dev.	0.52	0.35	0.28	0.55			0.45

[a] Scaled to X, the specified A-7 bombing accuracy.

A similar inspection of the ALOFT configuration data also indicates that results in all four modes are equivalent and can be characterized by a single set of statistical parameters. The COPPER configuration shows much the same behavior except in the straight path BARO mode where the results are significantly different from the other three modes. Since the bomb sample in this mode is only four and since the standard deviation of the entire COPPER sample is very close to the standard deviation of each of the samples, it is assumed that the difference in this one case is due to statistical variation and that in fact all modes are equivalent.

Thus, from the above analysis it can be seen that for comparisons to an accuracy of about 0.1X mil the entire sample of FLEET, ALOFT/COPPER, or ALOFT/FIBER OPTICS bomb drop data, or of any reasonable mixture of modes, can be used interchangeably without compromising the significance.

In a manner similar to that done for the analysis of mode-to-mode variation, the effects of flight-to-flight and pilot-to-pilot variation can be analyzed using Tables 2, 3, and 4. However, the flight-to-flight and pilot-to-pilot variation is considerably greater than that found in the analysis of mode-induced variation. In each of the three sets of data, pilot-to-pilot variation is greater than 0.2X mil and in one case (FIBER OPTICS) is as great as 0.55X mil. Whether this is a pilot-induced variation or flight-to-flight variation is impossible to determine because no pilot flew the same configuration twice. The significance of this degree of variation is that comparisons of data based on one or two different pilots have significantly reduced believability unless differences are in excess of a 0.2X to 0.3X mil. Even comparisons of data based on the same mix of pilots must be carefully treated since the variation observed could be flight-to-flight variation rather than pilot-to-pilot variation (as it is labeled for convenience).

Figure 12 gives the individual circular error probable (CEP) (from Tables 2, 3, and 4) as a function of time (ignoring any other differences). Any long-term trends in the data appear to be significantly less than short-term fluctuations.

The composite statistics from the bombing accuracy, Tables 2, 3, and 4, are given in Table 5.

TABLE 5. CEP Prime Mode Bombing Summary.

Configuration	Mean	Median	Std. dev.
FLEET	0.66	0.72	0.31
COPPER	0.94	1.01	0.40
ALOFT	1.02	0.94	0.45

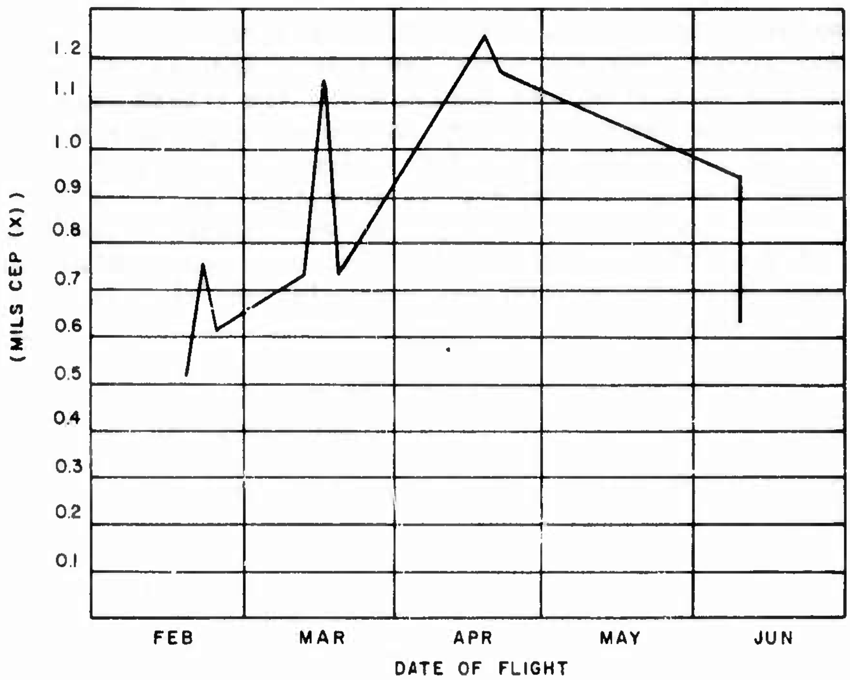


FIGURE 12. Temporal Variation of Bombing Accuracy (Prime Modes).

In Table 5 there is an apparent change in bombing accuracy between the FLEET and the COPPER configurations. Both the mean and median CEP show similar increases. The difference between COPPER and FIBER OPTICS configurations, however, appears minimal. The difference between FLEET and COPPER modes is anticipated since software and hardware differences exist between these configurations, and have nothing to do with the fiber optics technology under evaluation. Since the statistics used to arrive at these numbers are onesided (absolute miss distance), the increase in standard deviation for COPPER and FIBER OPTICS configurations cannct be linked directly to increased scatter in the data.

The fact that both pilots Harrel and Duncan flew FLEET and COPPER configurations, and both recorded degradations in CEP and standard deviation suggests strongly that this degradation is real. From a straight CEP analysis, the difference between the baseline (COPPER) performance and the FIBER OPTIC performance appears nonsignificant. Unfortunately, because the COPPER sample was small and the pilot-to-pilot variation was large, the data could be deceptive in that a statistical fluctuation is just as likely to nullify a real change as to create a false one.

Error Contributions. In order to explore the data more fully, it can be broken into its error contributions. The CEP makes a contribution due to randomness drop-to-drop and due to translation of the mean impact

point off the target. The movement of the mean impact point off target can further be broken down into an aircraft-dependent (e.g., bombing to the left), and an inertial term (e.g., bombing east of the target). Depending on the direction of flight, the aircraft-dependent term can appear random and can easily be overlooked.

Aircraft Bias. Table 6 gives the mean impact points, for the pertinent bombing accuracy flights, in aircraft coordinates and Table 7 gives the mean impact points in inertial (ground) coordinates. Table 6 represents where the bombs would hit if the plane flew the same direction on each flight, while the mean impact points in Table 7 are the actual bomb hits. In Table 6 it appears that in FLEET-configured flights, the pilots dropped their bombs close enough to the target that it can be assumed no significant aircraft bias exists. In the ALOFT/COPPER data, the bombs appear to fall short and to the left, although the left tendency is less consistent than the short tendency. Only two pilots/flights is far from a good sample.

In the data of Table 6, a very pronounced trend is clear. Bomb impacts showed a short and right of the target bias. The mean impact point is in the right lower quadrant and its expected (average) location is nearly 0.8X mil off target. Furthermore, if the indicated mean impact point for the COPPER configuration is correct, the aircraft bias shifted about 0.9X mil in the change from COPPER to FIBER OTPICS.

Table 7 indicates that the actual mean impact points show about 0.5X mil of inertial bias in both the FLEET and COPPER configurations. The FIBER OPTIC data show a true mean impact point 0.3X mil off target. Although the vast majority of mean impact points fall in the southwest quadrant, only in the western trend in the FLEET configuration is the trend both consistent and significant. Certainly, there is no significant change between the COPPER and FIBER OPTICS data. The fact that the mean impact point for the FIBER OPTICS configuration data is fairly close to the target indicates that in these flights, where the number of flights north-to-south (N-S) was equal to the number south-to-north (S-N), the bombing was consistent in both directions in aircraft coordinates and very little inertial bias was present.

Therefore, the bombing accuracy data indicate that a significant change in gross bombing accuracy accompanied the change from the FLEET configuration to the ALOFT/COPPER configuration. This change in accuracy was anticipated and indeed represents the reason for the ALOFT/COPPER flights, which was to establish a new baseline for the aircraft in the ALOFT/FIBER OPTICS modes. No further degradation in gross bombing occurred when the computer interface was changed to the FIBER OPTIC mode. Examination of mean impact points, however, indicates that a considerable shift in mean impact point occurred when the fiber optics were incorporated.

This apparent shift in aircraft alignment accounts for more bombing error in the FIBER OPTICS configuration than from all causes in the FLEET configuration (0.77X versus 0.66X). This alignment shift could be caused by physical alignment problems (however, a later check proved this untrue) or by electrical/HUD misalignments having nothing to do with ALOFT fiber optics.

TABLE 6. Prime Bombing, Aircraft Reference.[a]

Flight	Pilot	Date	No. of releases	Mean				
				X	Y	X	Y	Miss
582-54-73	Duncan	2/23/76	8	0.11	-0.37	...	...	...
582-51-71A	Harrel	2/20/76	8	-0.12	-0.01	...	...	...
582-49-69	Fleming	2/18/76	5	-0.19	-0.5	-0.05	-0.13	0.14
582-72-85	Duncan	3/12/76	8	-0.07	-0.22	...	...	...
582-73-77/78	Harrel	3/13/76	7	-0.45	-0.80	-0.26	-0.51	0.57
582-112-104	Tkach	4/21/76	8	0.98	-0.55	...	...	...
582-111-101A	Harrel	4/20/76	8	0.76	-0.47	...	...	...
582-160-153A	Kaufman	6/8/76	8	0.39	-0.46	...	...	...
582-161-158	Hezlep	6/9/76	7	0.27	-0.47	0.60	-0.49	0.77

[a] Scaled to X, the specified A-7 bombing accuracy.

TABLE 7. Prime Bombing, Inertial Reference.[a]

Flight	Pilot	Date	No. of releases	Mean				
				X	Y	X	Y	Miss
582-54-73	Duncan	2/23/76	8	-0.46	0.07	...	...	...
582-51-71A	Harrel	2/20/76	8	-0.57	-0.02	...	...	...
582-49-69	Fleming	2/18/76	5	-0.42	0.08	-0.49	0.04	0.49
582-72-85	Duncan	3/12/76	7	-0.53	-0.09	...	...	...
582-73-77/78	Harrel	3/13/76	7	-0.11	-0.65	-0.32	-0.37	0.49
582-112-104	Tkach	4/21/76	8	-0.20	-0.12	...	...	...
582-111-101A	Harrel	4/20/76	8	-0.64	-0.33	...	...	...
582-160-153A	Kaufman	6/8/76	8	-0.03	-0.42	...	...	...
582-161-158	Hezlep	6/9/76	7	0.32	-0.12	-0.15	-0.25	0.29

[a] Scaled to X, the specified A-7 bombing accuracy.

Bombing consistency (the tendency to bomb in the same place), was not degraded by the addition of FIBER OPTICS to the COPPER configuration baseline. This is shown by the standard deviations of the CEP data (0.4X for fiber optics and 0.45X for fiber optics), combined with the closeness of the mean impact point to the target in the FIBER OPTICS configuration (-0.15X, -0.25X), indicating that the misses N-S were about the same as those S-N.

BOMBING ACCURACY (NON-PRIME MODES)

Data

Two flights in the FIBER OPTICS configuration and one in the COPPER configuration were flown to verify weapon system moding and to verify bombing accuracy in backup modes. Variations from prime modes included combinations of: radar altimetry, doppler inertial gyro-compass, radar offset, and normal offset. A matrix of the various bomb drops is given in Appendix C, Table C-3. The results of the drops are given in Table 8. All drops were successful in both configurations, indicating that moding for all of the various combinations tried was successful.

TABLE 8. Bombing (Non-Prime Modes).[a]

Passes	Q COPPER 582-75-90			FIBER OPTICS 582-140-145C			FIBER OPTICS 582-162-159		
	REP	DEP	CEP	REP	DEP	CEP	REP	DEP	CEP
1	-0.65	-0.38	0.75	0.02	1.83	1.83	-0.25	0.39	0.46
2	-1.04	0.26	1.07	-1.30	1.20	1.77	-0.74	0.53	0.91
3	0.08	0.35	0.36	0.30	0.33	0.45	0.07	0.76	0.76
4	0.15	-1.33	1.34	-0.50	0.35	0.61	0.56	0.56	0.79
5	2.74	-2.00	3.39	-1.56	-0.57	1.66	-0.63	0.10	0.63
6	3.22	1.91	3.74	-3.40	0.05	3.40	-0.76	7.09	7.13
7	-0.05	-0.76	0.76	-0.81	2.10	2.25	-1.52	-0.22	1.53
8	2.03	1.44	2.48	-5.40	-1.12	5.51	-6.55	-1.46	6.71
9	-0.26	1.03	1.07	-8.32	-0.33	8.32	8.11	4.45	9.29
10	-1.64	10.13	10.26	-1.19	1.75	2.11	-5.68	-13.0	5.83
Mean			2.5						1.8
Median			1.2						3.1
Standard deviation			2.8						2.8

[a] Scaled to X, the specified A-7 bombing accuracy.

Analysis

Because only three drops (one COPPER and two FIBER OPTICS) were made in each of the modes during these flights, it is not possible to compare the results on a mode-for-mode basis. Therefore, the results of all 10 drops in copper and the 20 drops in fiber optics were compared collectively. The results are summarized in Table 9.

TABLE 9. Comparison of All COPPER Versus All FIBER OPTICS Drops.

Bomb impact	COPPER	FIBER OPTICS
Mean	2.5X	1.8X
Median	1.2X	3.1X
Standard deviation	2.8X	2.8X

The results given in Table 9 are not as straightforward as those previously analyzed. The difference between the means and medians indicates the data are not as well behaved as that previously reviewed.* This is not a surprise since the bombing modes grouped here for analysis vary considerably in inherent accuracy, unlike previous data that were produced from modes of very similar inherent accuracy. The change in mean and median taken together as an indicator of performance does not appear to denote a significant change. The constancy of the standard deviation further indicates that no change has taken place between the COPPER and FIBER OPTICS configurations, as it shows that the two samples have about the same proportion of close and far misses.

MISCELLANEOUS BOMBING

Data

In addition to the bombing accuracy tests described earlier, a variety of bombing runs were made with various weapons and delivery tactics to verify weapons system moding and minimum release interval (MRI) equations. The flights used the following weapons: Mk 82, Mk 76, Mk 106 XCM and flares, Mk 83, M-61 (gun) (not done in COPPER), and rockets (not done in COPPER).

* It must be noted that a 2:1 or 3:1 change in bombing accuracy in one of the more accurate modes could easily be missed in this analysis, but no other analysis is possible due to the paucity of data.

Stations used for these tests included: Parent 1, 2, 3, 6, 7, 8; multiple ejector rack (MER) on 2 and 7; triple ejector rack (TER) on 2 and 7; and LAU-3 on the TER.

Deliveries included level, straight-path, and dive-toss with a variety of *g* loads.

Matrices given in Tables 10 and 11 indicate the bombing combinations used in both COPPER and FIBER OPTICS flights.

In the COPPER configuration, four flights were flown consisting of the bombing passes given in Table 10. The table also gives the bombing results from these drops including:

Central miss distance--the distance from the center of the stick to the target.

Stick length--distance from the first bomb to the last.

Average bomb interval--the stick length divided by the number of bombs less one.

Mean deviation from the average interval--the mean of the difference between the average bomb interval and the actual bomb interval.

Moding check--indication that the moding functioned correctly.

Skew--the mean deviation from the average interval divided by the stick length.

Analysis

Most of the data listed above are self-explanatory. The mean deviations from the average interval and the skew are measures of the bomb interval error in that the higher the skew, the more asymmetrical is the bomb impact pattern. For instance, drop 6 (Table 10) was highly symmetrical, while drop 9 was very unsymmetrical.

Very little can be said about the bombing data in the COPPER configuration. Any statistic on bombing accuracy is contaminated severely by the Mk 106 drops which exhibited exceedingly long miss distances but were of average symmetry. The most important data are the average skew of 0.19 and the moding success in each mode.

The results of the miscellaneous bombing in the FIBER OPTICS configuration are presented in Table 11. Again successful moding for each delivery type is indicated. The significant indication that nothing has changed in the bombing due to the fiber optics is the mean skew which, at 0.16, remained virtually unchanged from the COPPER configuration value of 0.19.

TABLE 10. COPPER Configuration Miscellaneous Bombing.[a]

Drop	Passes	Wpn/ASCU code	Qty/ int., ft	Rack/ stations	Del. mode	Attack mode	g	MRI class	Central miss (X)[a]	Stick length	Average interval	Mean deviation from average interval	Moding check	Skew
1	1	Mk 82 LDGP/ XGO	03/010	Parent/ 1, 8, 2	St. path	Normal	<1	III	0.91	41.3	20.7	14.5	✓	0.35
2	1	Mk 82 LDGP/ XGO	03/010	Parent/ 7, 3, 6	Dive-toss	Normal	>2	III	0.11	75.9	38.0	5.4	✓	0.07
3, 4	2	Mk 76/ XHR	03/010	MER/2	Dive-toss	Normal	>2	I, II	0.64 0.82	119.0 130.9	59.5 65.4	26.6 24.3	✓	0.22 0.19
5, 6	2	Mk 76/ XHR	03/010	MER/2	St. path	Normal	<1	I, II	1.05 0.45	98.2 124.8	49.1 62.4	4.8 2.9	✓	0.05 0.02
7	1	Mk 106/ XHP	03/010	MER/7	St. path	Normal	<1	I, II	14.0	257.3	128.4	46.4	✓	0.18
8	1	Mk 106/ XHP	03/010	MER/7	Level	Manual ripple	1	I, II	59.9	337.3	168.7	41.3	✓	0.12
9	1	Mk 83 con/ XGS	03/010	Parent/1 MER/7	St. path	Manual ripple	<1	II Safety feature	4.34[b]	126.5[b]	63.2[b]	57.2[b]	✓[b]	0.45
10	1	Mk 83 con/ XGS	03/010	Parent/8 MER/7	Dive-toss	Manual ripple	>2	II Safety feature	2.4	155.0	77.5	30.4	✓	0.20
													Mean skew	0.[illegible]9

[a] Scaled to X, the specified A-7 bombing accuracy.
[b] Verified release inhibit.

TABLE 11. FIBER OPTICS Configuration Miscellaneous Bombing.[a]

Drop	Passes	Wpn/ASCU code	Qty/ int., ft	Rack/ stations	Del. mode	Attack mode	g	MRI class	Central miss (X)[a]	Stick length	Average interval	Mean deviation from average interval	Moding check	Skew
1, 2	2	Mk 82 LDGP/ XGO	03/010	Parent/ 1, 8, 2	St. path	Normal	<1	III	0.74	47	23.5	10.4	✓	0.4
3, 4	2	Mk 82 LDGP/ XGO	03/010	Parent/ 7, 3, 6	Dive-toss	Normal	>2	III	4.4	70.3	35.2	17.7	✓	0.16
5	1	Mk 76/ XHR	03/010	MER/2	Dive-toss	Normal	>2	I, II	2.2	128.2	64.1	25.0	✓	0.19
6	1	Mk 76/ XHR	03/010	MER/2	St. path	Normal	<1	I, II	1.4	212.8	106.4	14.9	✓	0.07
	0	Mk 106/ XHP	03/010	MER/7	St. path	Normal	<1	I, II					✓[a]	
	0	Mk 106/ XHP	03/010	MER/7	Level	Manual ripple	1	I, II					✓[a]	
7	1	Mk 83 con/ XGS	03/010	Parent/1 MER/7	St. path	Manual ripple	<1	II Safety feature	24.7	262.9	131.5	29.9	✓	0.11
8	1	Mk 83 con/ XGS	03/010	Parent/8 MER/7	Dive-toss	Manual ripple	>2	II Safety feature	7.9	180.5	90.3	0.6	✓	0
													Mean skew	0.19

NOTE: Pilot elected not to drop according to matrix on data flight but moding verified in non-data flight.
a Scaled to specified A-7 bombing accuracy -X.

GUNS AND ROCKETS

Data and Analysis

In the FIBER OPTICS configuration two flights were made using the M-61 gun and 2.75-inch rockets, with proper moding and weapons control. No theodolite data were taken for miss distance of the gun although direct observation data are given in Table 12. The table is qualitative but does indicate that the gunfire was within proper operational tolerances.

TABLE 12. Gunfire Results.

Pass	Miss X, ft	Miss Y, ft
1	0	15
2	0	0
3	-50 to +20	0
4	10 to 50	0
5	0 to -75	0
6	-50	0

The results of the rocket firings are given in Table 13. The table indicates that the rocket firings were all within normal A-7E performance bounds.

TABLE 13. Rocket Results.[a]

Flight	Mean CEP	Std. dev.	Mean error (A/C ref)			Mean error true		
			E-W	N-S	Radial	E-W	N-S	Radial
782-149-150	0.47	0.31	-0.28	0.038	0.28	0.074	-0.028	0.079
782-148-148	1.12	0.54	0.32	0.087	-0.43	-0.43	0.0	0.43

[a] Miss distance scaled by X, the specified A-7 bombing accuracy.

NAVIGATIONAL UPDATE

Data

From 23 January to 15 July 1976, 15 navigational flights were evaluated. Three were flown in the normal FLEET configuration and three were flown in an ALOFT/COPPER configuration. The remaining nine flights were flown in the FIBER OPTICS configuration.

All flights were made over the same range which had good, regularly spaced, visual- and radar-update points. The direction and amount of navigation error recorded by the pilot at each of these points provided the majority of data used in the analysis.

Two basic modes of navigation were used during the flights, inertial and doppler inertial gyrocompass (DIG). Most of the flights used one mode or the other, but not both. Updates were made using a well-dispersed mixture of HUD and radar with either FLR, BARO, or RAD ALT ranging. Table 14 shows the mixture of update modes/techniques used. Figure 13 shows the navigational error CEPs found during those flights as a function of time, indicating that any long-term temporal effects (e.g., drift) are submerged well below short-term effects.

TABLE 14. Number of Flights in Each Update Mode.

Update/ranging	FLEET	COPPER	FIBER OPTIC
Inertial			
HUD BARO	2	1	14
HUD FLR	3	3	13
HUD RAD ALT	3	1	8
RADAR BARO	3		13
Doppler			
HUD BARO	5	7	10
HUD FLR	6	9	10
HUD RAD ALT	4	3	13
RADAR BARO	4	6	8

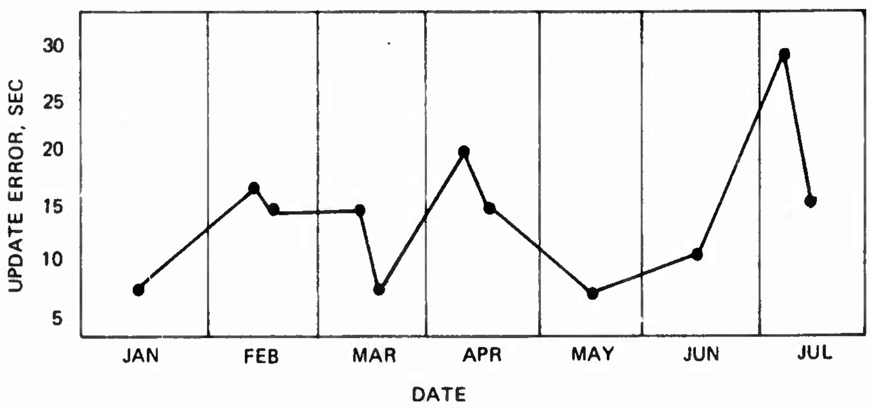


FIGURE 13. ALOFT Update Error CEP by Date.

Analysis

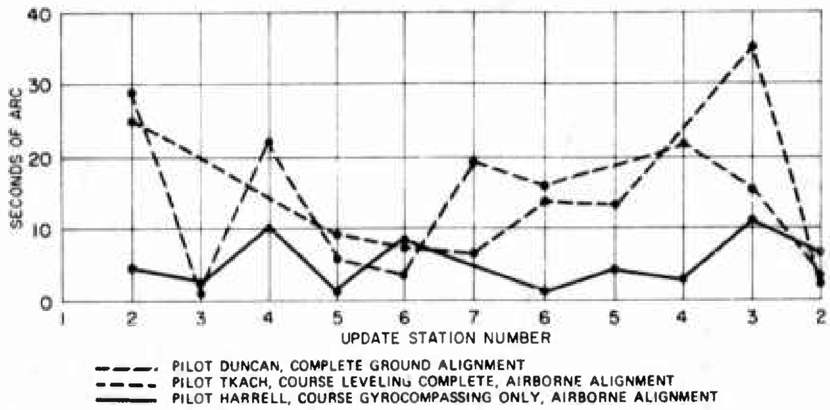
Pilot Variability. As in the analysis of bombing data, the ultimate limitation to the fineness of the comparisons of FLEET, COPPER, and FIBER OPTICS configuration data is the uncontrolled variability in the data. For this reason, variability in pilots' capabilities must be examined, since no pilot flew sufficient numbers of modes/techniques for each configuration to provide a good comparison; the comparisons that can be made are based on insufficient numbers of pilots to "average out" pilot-to-pilot variability.

Table 15 gives the mean navigational update errors obtained for each pilot and flight making up the data set. The variability shown in the table is as great as 5:1 flight-to-flight and pilot-to-pilot, and 2:1 for a single pilot within one navigational mode and equipment configuration (see Duncan and Kaufman). With this great degree of variability and the relatively small number of pilots/flights forming the basis of each major set of data (NAV mode and configuration) (ignoring update mode variation), differences observed could not be considered significant unless their magnitude is greater than 5-10 seconds.

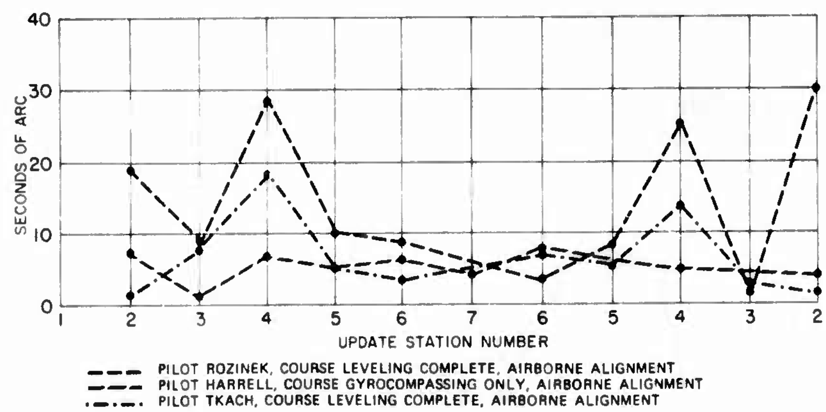
TABLE 15. Mean Navigational Update Errors.

Date	Configuration	Mean of error, arc sec	Pilot
Inertial, No. 1			
23 January	FLEET	5	Harrel
13 Arpil	FIBER OPTICS	17	Tkach
16 June	FIBER OPTICS	8	Duncan
15 July	FIBER OPTICS	17	Duncan
DIG, No. 3 and 4			
23 February	FLEET	15	Tkach
24 February	FLEET	14	Duncan
15 March	COPPER	14	Rozinek
16 March	COPPER	5	Harrel
21 April	FIBER OPTICS	12	Kaufman
17 May	FIBER OPTICS	5	Fleming
8 July	FIBER OPTICS	29	Kaufman

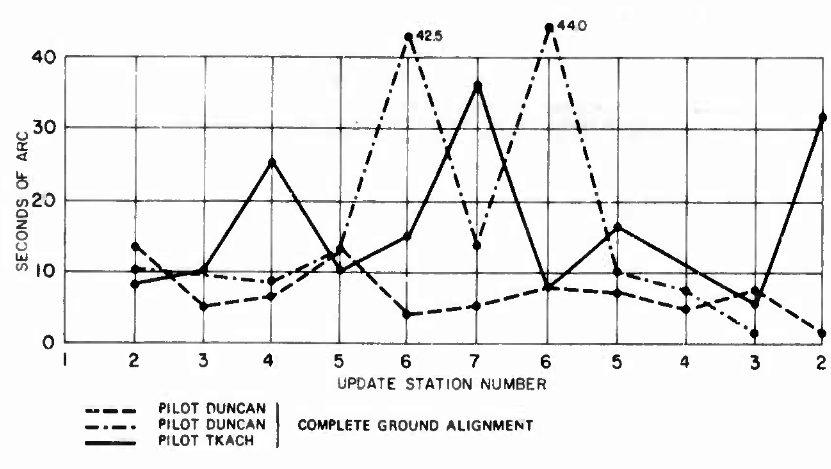
Update Error. Figure 14 gives the distribution of navigational update error for the various update targets. The update station numbers shown in the figures are known geographic locations. The figures indicate



(a) FLEET flights; inertial and doppler inertial gyrocompassing NAV mode.

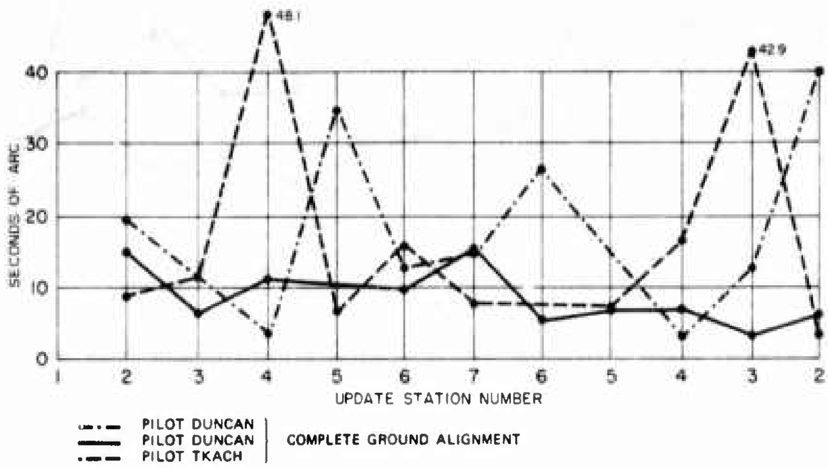


(b) COPPER flights; inertial/doppler inertial gyrocompassing and doppler inertial gyrocompassing NAV mode.

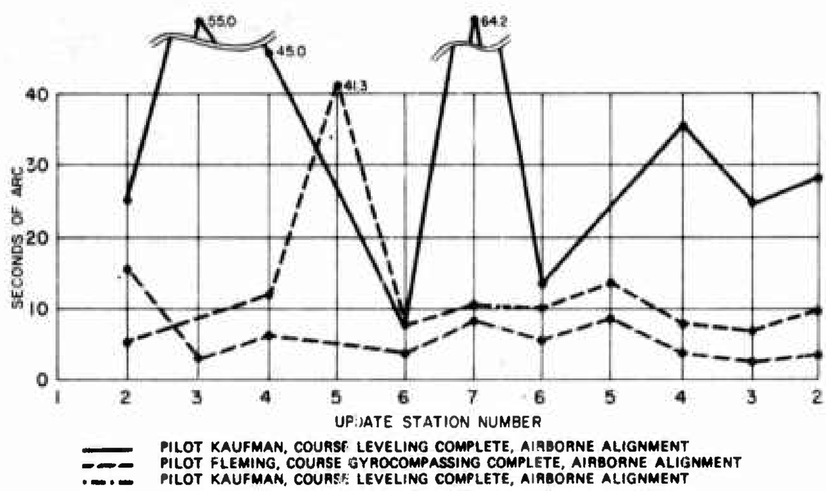


(c) FIBER OPTIC flights; inertial NAV mode.

FIGURE 14. Distribution of Navigation Update Error by Signal Transmission Method, Navigation Modes, and Alignment Method.



(d) FIBER OPTIC flights; inertial/doppler inertial gyrocompassing NAV mode.



(e) FIBER OPTIC flights; doppler inertial gyrocompassing.

FIGURE 14. (Contd.)

that no one target is consistently good or bad and that update variability found pilot-to-pilot and flight-to-flight extends to the individual update. The individual update accuracies obtained for different targets on a single flight vary by as much as 10:1 and, in fact, successive updates against the same target by the same pilot on the same flight show similar variability.

Figure 15 gives histograms showing the distributions of error amplitude for each of the update modes and equipment configurations. Separation of both update modes and configurations was not possible in the FLEET and COPPER configurations due to the lack of data taken. The histograms indicate an apparent loss of update accuracy in the FIBER OPTICS configuration and especially in the inertial update mode compared to the FLEET and COPPER configuration results, although the magnitude of the apparent degradation is not easily determinable.

Table 16 gives the navigational update error CEP (in arc sec) for the configurations and update modes shown in the histograms, along with the number of updates forming each sample. The table does indicate that the FIBER OPTICS configuration was apparently degraded, especially in the inertial mode. However, this degradation is only in the order of 3 seconds of arc and is therefore well within the experimental variability expected due to the lack of sufficient data.

TABLE 16. Update Error CEP (Median).

Configuration	Navigation mode, arc sec					
	Inertial		DIG		All	
	Navigation update error	Number of samples	Navigation update error	Number of samples	Navigation update error	Number of samples
FLEET	...	...	...	...	8.3	31
COPPER	...	...	...	...	6.1	30
FLEET and COPPER	4.1	16	7.1	45	7.0	61
FIBER OPTICS	10.3	49	8.3	42	10.0	91

Table 16 is a summary of the data given in Table 17, broken down to show the expected (mean) error and the standard deviations of the data. The table indicates that in most cases the expected error (mean error) is small compared to the dispersion in the data and the CEPs of Table 16. However, the data indicate that at least the dispersion is greater in the FIBER OPTICS data than in the FLEET and COPPER data.

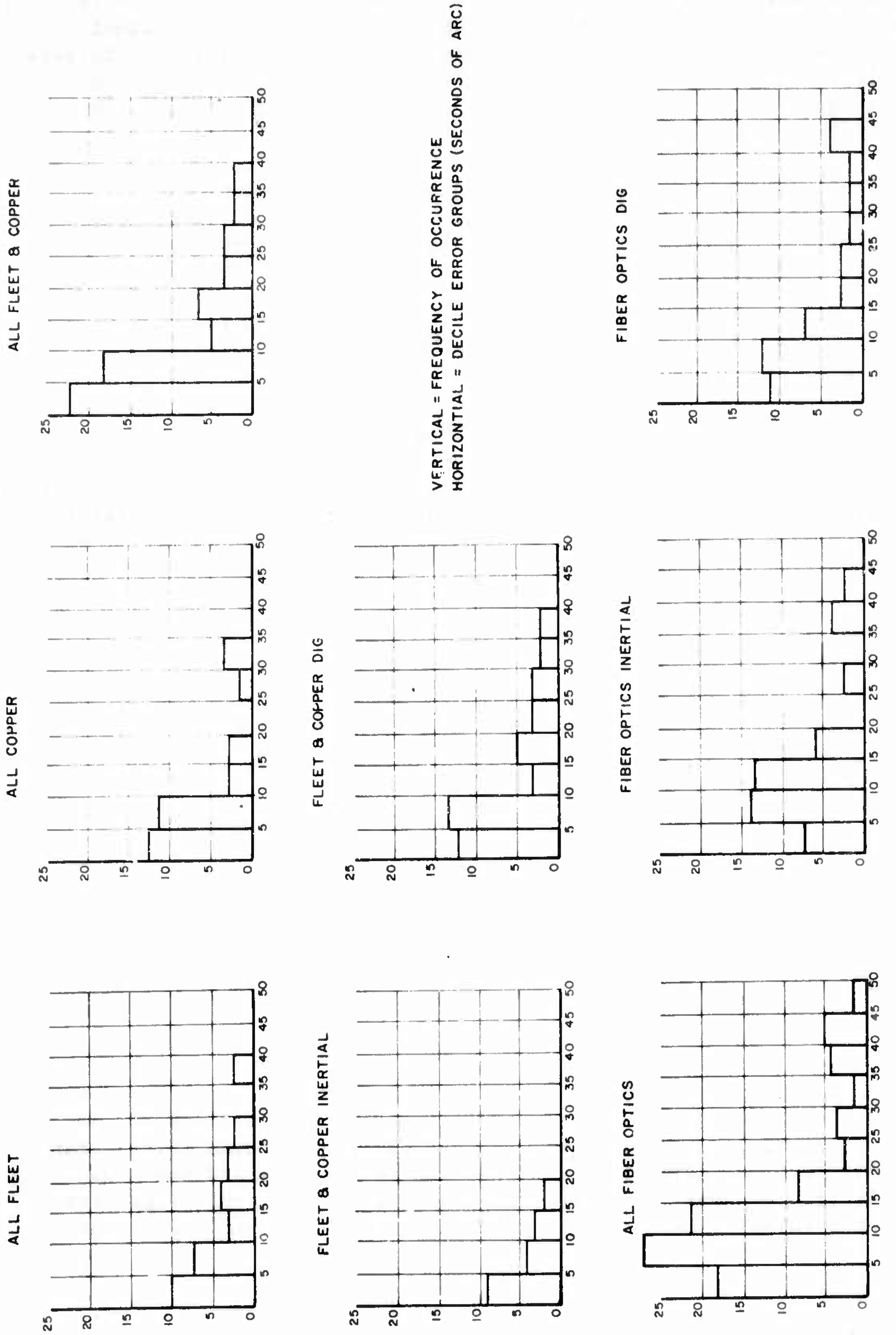


FIGURE 15. Distribution of Error Amplitude for Each Update Mode/Configuration.

TABLE 17. NAV Update Error Breakdown.

Configuration	NAV mode	Mean error, arc sec			Standard deviation	
		N-S	E-W	Radial	N-S	E-W
FLEET	All	-1.0	+1.5	1.8	11.0	9.4
COPPER	All	-0.1	-2.4	2.4	9.9	6.3
FLEET and COPPER	Doppler	-0.6	-0.5	0.8	12.0	9.4
FLEET and COPPER	Inertial	-1.2	-0.5	1.3	6.2	3.5
FLEET and COPPER	All	-0.8	-0.5	0.9	10.5	8.2
FIBER OPTIC	Inertial	-0.3	-3.1	3.1	15.0	13.0
FIBER OPTIC	Doppler	+1.6	+0.5	1.7	20.0	9.0
FIBER OPTIC	All	+0.6	-1.4	1.5	17.0	11.0

Although the differences between the FLEET/COPPER data and the FIBER OPTICS data are small compared to the expected pilot/flight variability, the consistency of the apparent degradation prompted a test of its significance. The results of the test are shown in Table 18. The low Z-values found in the table indicate that the data are not sufficiently different to conclude that they are samples of different populations.*

TABLE 18. NAV Update Significant Test Results.

FLEET/COPPER / FIBER OPTICS	Inertial		Doppler		All	
	N-S	E-W	N-S	E-W	N-S	E-W
Inertial	0.34	1.28				
Doppler			0.61	0.50		
All					0.61	0.56

NOTE: The inertial comparison is based on virtually one particularly good FLEET configuration flight by Pilot Harrel.

This lack of difference between the configurations is further emphasized in Figure 16 where the actual update errors are plotted. These plots qualitatively verify that the FIBER OPTICS data are indistinguishable from the FLEET/COPPER configuration data.

* A Chi-square correlation was applied which determines the probability that two independent samples, having different means and variances, could have been drawn from the same parent population. The Z-values are the two-sided probabilities associated with the normal (Gaussian) distribution.

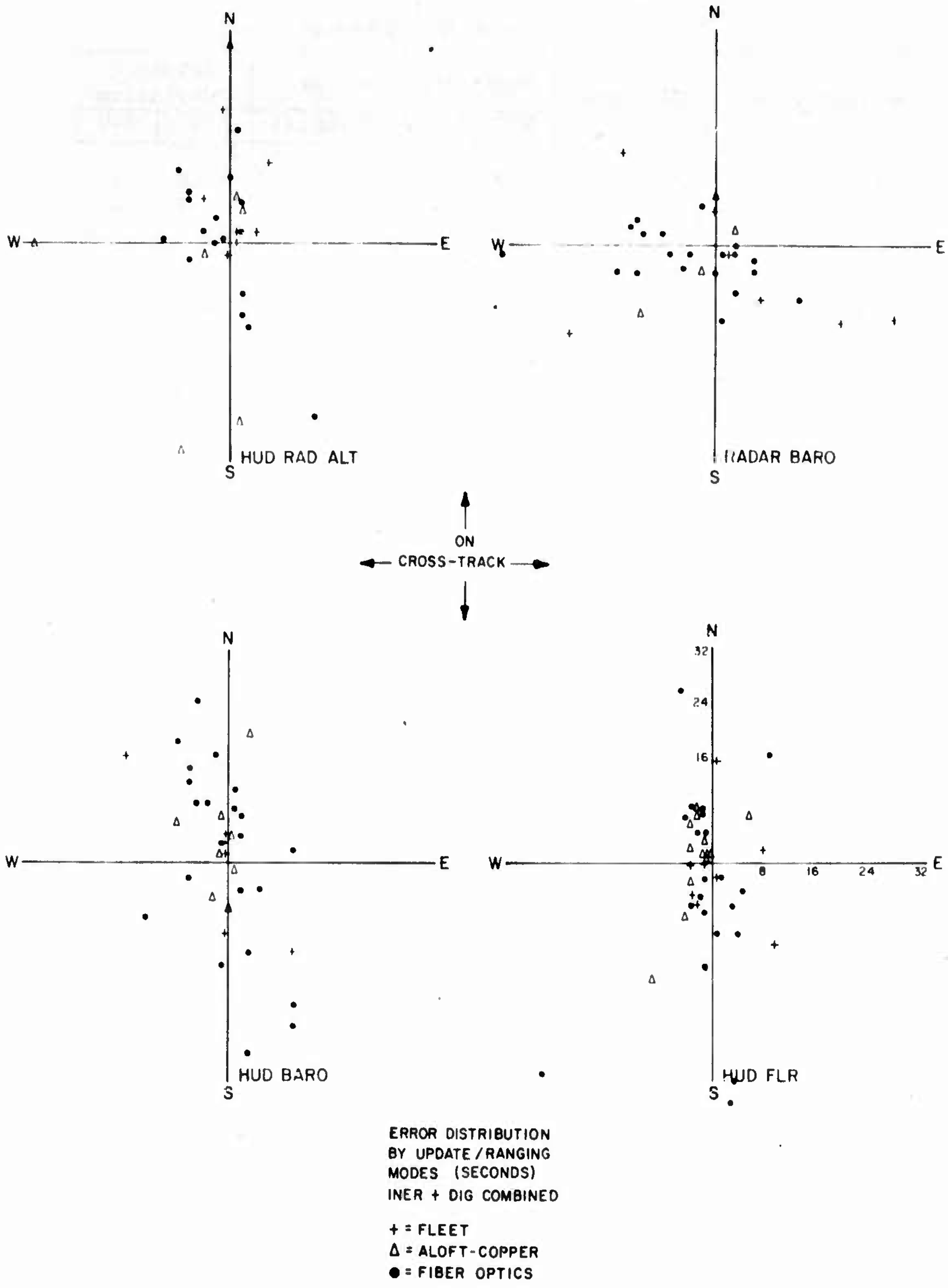


FIGURE 16. Error Distribution Plots by Update/Ranging Modes.

WIND CORRECTION

Data

Wind data are taken by flying the aircraft in a box with north, south, east, and west legs, and determining wind velocity (direction and speed) from the difference between ground velocity and indicated air velocity. Dispersion in the data so derived is taken as a measure of inertial measurement unit (IMU) drift. The more the dispersion, the poorer the IMU data. Because the measurement is more difficult to make at low wind speeds and of least significance to bombing there, the dispersion is most important at higher wind speeds, e.g., above 10 knots.

Wind data were taken on 30 trials of all three configurations (8 FLEET, 5 COPPER, and 17 FIBER OPTICS). The results are given in Table 19. Of these, COPPER trials 1 and 2 and FIBER OPTICS trials 1, 2, 11, and 12 have serious errors where the wind appeared to change direction with the aircraft. These data are therefore rejected as hardware-induced failures. The remaining data were analyzed to determine mean and median direction and wind velocity. The standard deviation of both the direction and velocity for each trial was taken as a measure of measuremental dispersion. The results are summarized in Table 20.

Analysis

Table 20 gives the means and medians of the standard deviations of the data in Table 19. The mean and median standard deviations do not differ significantly between FLEET and COPPER configurations for either wind direction or velocity. In the COPPER to FIBER OPTICS configuration, the dispersion in the wind velocity data increases significantly while dispersion in the direction component remains unchanged. These relationships are also true for the data representing trials with mean velocity over 10 knots.

The change in the FIBER OPTICS data of about 2:1 over FLEET configuration is due, at least in part, to the fact that the mean wind velocity during the FIBER OPTICS trials was significantly above that for the FLEET configuration trials (17 FIBER OPTICS to 11 FLEET) and the data clearly indicate that larger wind velocity errors are associated with higher wind velocities. In this case, the COPPER configuration data are too sparse to draw any real comparison between the FIBER OPTICS and COPPER configurations. Therefore no significant degradation due to fiber optics is indicated in the wind data.

TABLE 19. Wind Data.

Configuration trials	Mean velocity, knots	Std. dev. velocity, knots	Std. dev. direction, deg	Mean, med., std.	
				All	>10 knots
FLEET:					
1	8.5	2.9	18.6		
2	26.3	6.3	10.9	Mean 3.3	3.9
3	7	3.3	14.3	Med. 3.1	4.0
4	11.5	1.5	15.5	Std. 1.3	2.0
5	6.8	2.4	26		
6	7	2.5	12.8	Mean 23.5	21
7	10.3	4.0	35	Med. 17.1	26
8	9.5	3.4	55	Std. 14	10
COPPER:					
				Mean 2.2	2
1[a]	4.3	8.3	92	Med. 2.5	2
2[a]	10	1.2	83	Std. 0.5	0.5
3	9.8	2.7	39		
4	15.8	2.5	3.6	Mean 17	5.8
5	13.5	1.5	8	Med. 8	5.8
				Std. 16	2.2
FO:					
1[a]	9.3	2.6	102		
2[a]	6	2.5	91		
3	34.8	18.8	73		
4	31.5	10.2	7.6		
5	10.5	4.6	21		
6	10	4.9	13		
7	12	6.0	33	Mean 7 4	7.9
8	9.5	6.7	33	Med. 5.9	5.9
9	10.8	1.1	39	Std. 5.6	5.8
10	17.3	4.3	27		
11[a]	6	3	75	Mean 32	27
12[a]	4.5	1.1	79	Med. 27	24
13	15.3	4.3	28	Std. 21	17
14	16.8	5.9	19		
15	25.3	20.2	14		
16	19.0	6.8	24		
17	7.3	2.5	80		

[a] Not included in analysis due to non-ALOFT hardware failure.

TABLE 20. Wind Data Statistics.

Winds	FLEET		COPPER		FIBER OPTICS	
	Velocity, knots	Direction, deg	Velocity, knots	Direction, deg	Velocity, knots	Direction, deg
All data:						
Mean	3.3	24	2.2	17	7.4	32
Median	3.1	17	2.5	8	5.9	27
Std. dev.	1.3	14	0.5	16	5.6	21
>10 knots:						
Mean	3.9	21	2.0	5.8	7.9	27
Median	4.0	26	2.0	5.8	5.9	24
Std. dev.	2.0	10	0.5	2.2	5.8	17

RESULTS AND COMMENTS

The ALOFT demonstration was conducted to confirm that fiber optic technology is mature and practical for use in internal aircraft data signal transmission. The flight test and evaluation of the system was the first demonstration of the feasibility of using fiber optics in a full system application in an operational environment. Previous demonstrations of this technology in the United States were limited to laboratory-level or small-scale flight evaluations at subsystem level.

Qualitative analysis of the ALOFT system performance by pilots, engineers, and technicians associated with the program states that the ALOFT system performs as well as a well-groomed fleet A-7 aircraft. Analysis of the ALOFT flight test data confirms this evaluation.

As a result of the analysis performed on the data gathered from both the baseline and demonstration flights, normal aircraft moding was unaffected by the ALOFT computer and its associated software modifications or by the fiber optics themselves.

A degradation in bombing accuracy concurrent with the change from the FLEET to ALOFT/COPPER aircraft configuration was significant but expected, and had nothing to do with the fiber optic technology. A flight shift in mean impact point also occurred when the aircraft was reconfigured from ALOFT/COPPER to ALOFT/FIBER OPTICS, but did not affect bombing consistency or overall accuracy. Unconfirmed speculation attributes this shift to a malfunctioning IMS unit that required replacement concurrent with the configuration changeover.

Backup mode bombing, as well as bombing in sticks, with various weapons, and firing guns and rockets all showed no effect as a result of the fiber optic data transmission.

No statistically significant change in the navigational update capability of the aircraft resulted from the fiber optics data transmission method.

During wind tests, an apparent decrease in the accuracy of data was due to higher wind velocity during the FIBER OPTIC aircraft configuration flights than were experienced in the COPPER configuration.

Appendix A
DETAILED TECHNICAL DESCRIPTION

MULTIPLEXING/DEMULTIPLEXING

Multiplexing/demultiplexing (MUX/DEMUX) employed by the ALOFT system was of the time division type. Figure A-1 shows a typical MUX/DEMUX method used to transmit data between the computer E/O adapter and the external unit and the area E/O adapters. All fiber optic links used the 50-kHz clock provided by the computer for 50-kHz serial I/O channels as a trigger for data transmission except the navigation and weapons delivery (NAV/WD) panel and the direct analog link to the ADI.

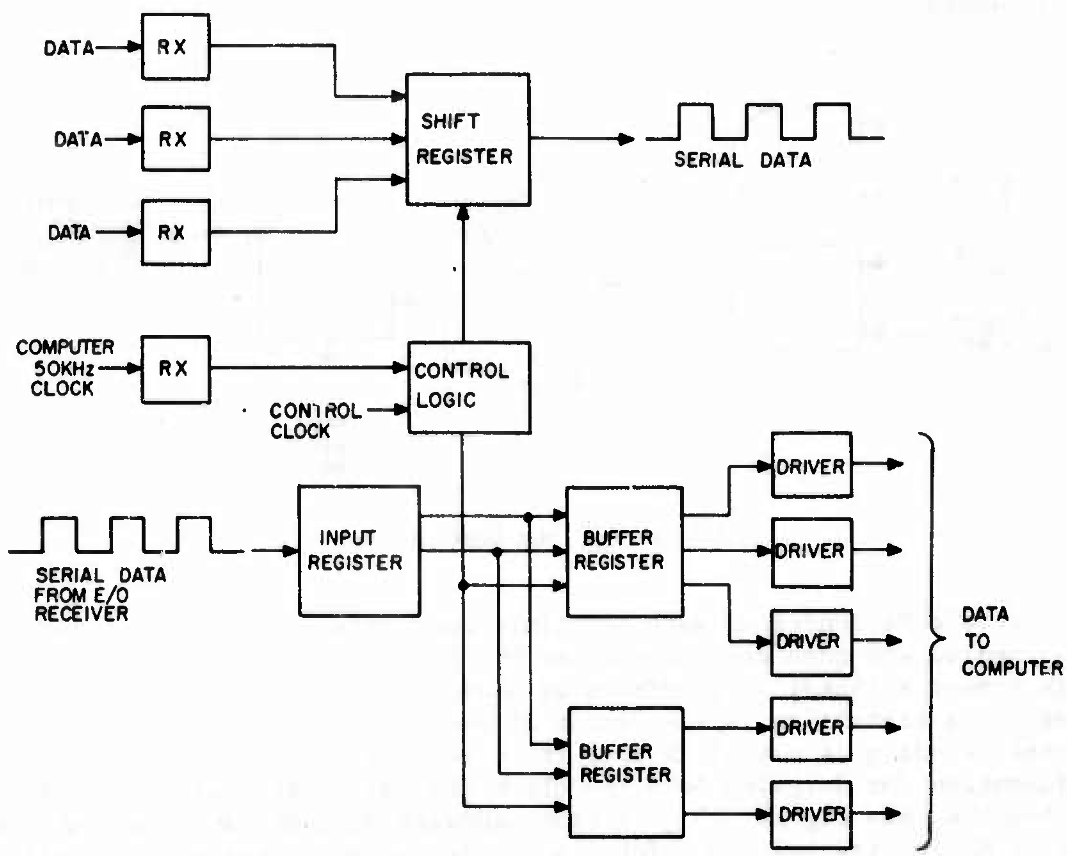


FIGURE A-1. Typical MUX/DEMUX Method.

Transitions of the 50-kHz clock trigger the control logic for the link. The output data are then parallel-loaded into a register and serially shifted out. The control logic also keeps track of the number of bits being sent out and terminates transmission when the last data bit is sent. Input data that come into the DEMUX logic from the E/O receivers are shifted into an input register. The data are then parallel-loaded into a buffer register and transmitted to the appropriate computer input line.

Manchester Encoder

The serial data that are transmitted from the computer to the area adapters are Manchester-encoded prior to being converted to optical signals by the E/O drivers. Manchester coding allows both data and clock to be combined into self-clocking waveforms. Figure A-2 shows a diagram of a typical Manchester encoding circuit as used in the ALOFT system.

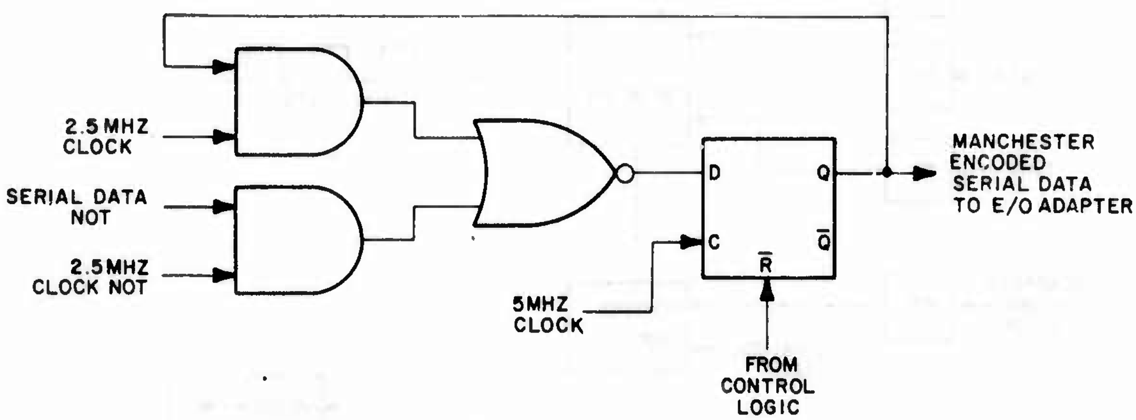


FIGURE A-2. Manchester Encoder.

At the beginning of each bit time, the serial data being transmitted are sampled and then complemented at the center of the bit period. In this manner a signal is generated as depicted in Figure A-3. Note that there is a transition in the center of each bit time. This type of signal encoding is useful in that it is self-clocking. The necessary information for deriving both the clock and serial data is contained within the same signal. Significant hardware savings can be accomplished with a Manchester-coded waveform, an important advantage when retrofitting a system into an already loaded aircraft. For the ALOFT system, an oscillator is employed to generate a control clock only in the computer E/O adapter. In the other adapters the input, a Manchester-coded signal, is used to generate the data-sampling clock and the necessary timing to transmit data back to the computer. The control logic also

enables and resets the output flip-flop of the Manchester encoder so that a synchronization bit is generated at the beginning of each transmission. When the last bit is sent out, transmission is terminated. As a result, the data transmitted over the I/O links are in the form of a series of bursts at a given repetition rate.

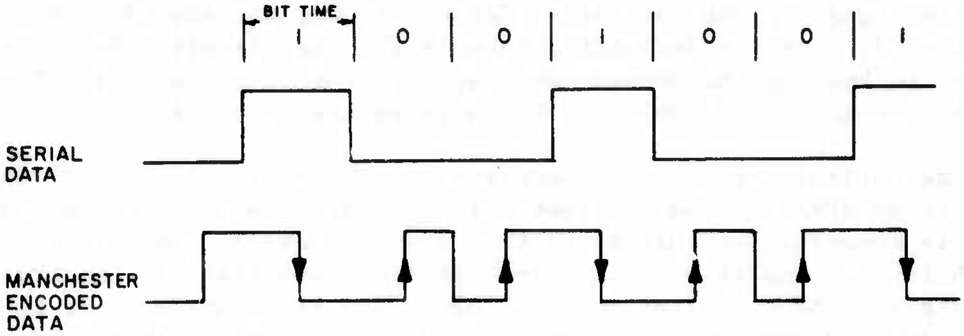


FIGURE A-3. Manchester-Encoded Serial Data.

OPTICAL INTERFACES

The optical interfaces used in the ALOFT system consist of point-to-point transmission from an E/O driver circuit, through the FO cable, to an E/O receiver circuit.

The driver circuit used in the ALOFT system, shown in Figure A-4, serves to convert electrical signals (the Manchester-coded, serial output of the multiplex logic) to light pulses.

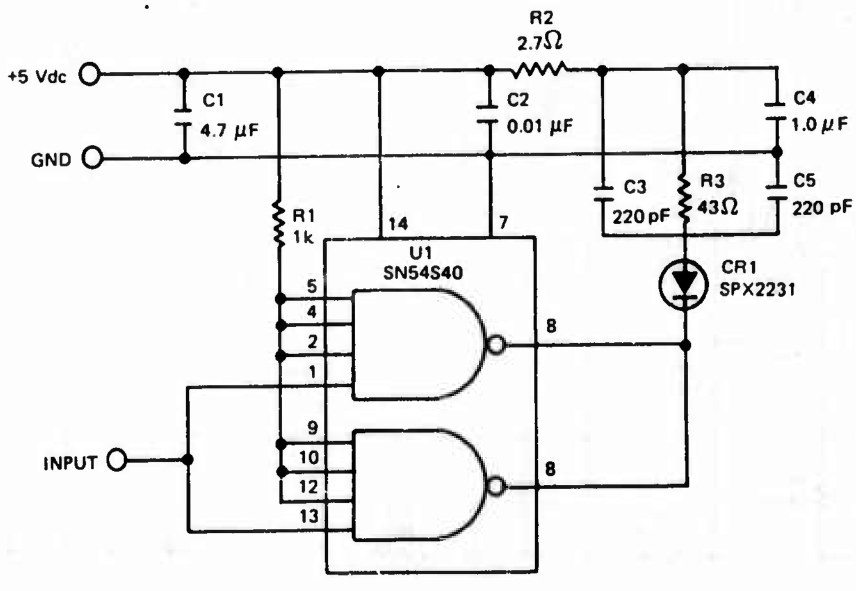


FIGURE A-4. Schematic of ALOFT E/O Driver Circuit.

Logic level inputs are used to switch the SN54S40 dual NAND gate that turns the current on and off through the SPX-2231. Resistor R3 sets the DC through the LED, while capacitors C4 and C5 produce a current pulse about five times the value of the DC. The current pulse compensates for the loss in bandwidth at the receiver preamplifier, giving the preamplifier a flat frequency response throughout the operating range of the receiver. Capacitors C1, C2, and C3, along with resistor R2, form the decoupling network for the circuit. Resistor R1 is used to hold up the unused gate inputs. The output of the driver is routed through the FO cables to the appropriate receivers.

The optical input to the receiver is coupled to the photodiode (PD) which is an HP4207. The receiver circuit (Figure A-5) shows how optical power is converted to current in this silicon device. The signal from the PD is then amplified by a transimpedance amplifier (Q1 and Q2), which converts the input current to a voltage. The transimpedance of the amplifier is approximately equal to R1 or 5,000 ohms. The second stage of the transimpedance amplifier also acts as a paraphrase amplifier that creates a differential input which is AC-coupled to the video amplifier V1 (SE592). The value of the AC-coupling is set to band-limit the receiver noise output. Inductor L1, damped by R20, is used for stability. The differential input video amplifier has a single-ended output with a gain of 200.

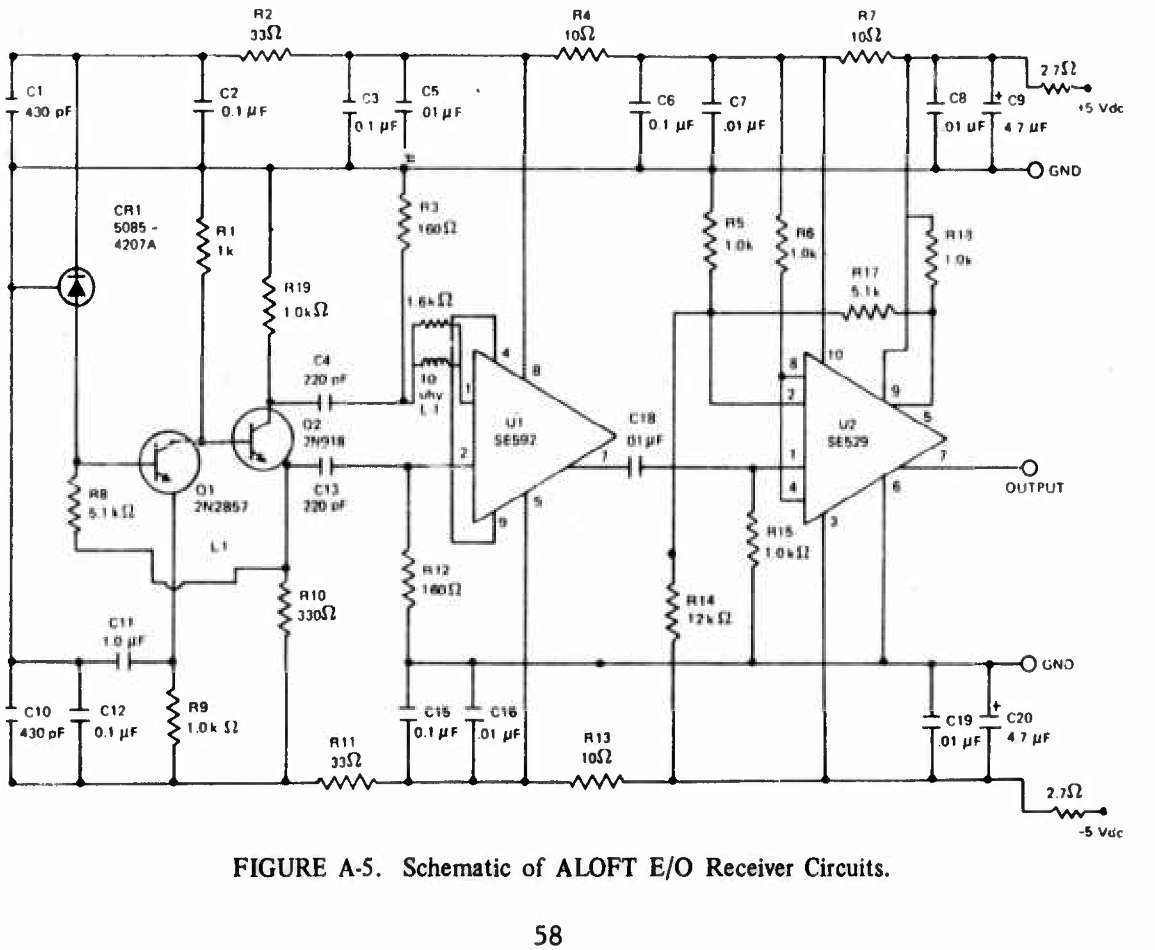


FIGURE A-5. Schematic of ALOFT E/O Receiver Circuits.

The output of the video amplifier is sent to a comparator U2 (SE 529), where it is threshold-detected and amplified. This device also has an internal Schottby gate which serves as the standard TTL output driver. In order that the threshold for both zero-to-one and one-to-zero be equal, the comparator is connected as a Schmitt trigger via the feedback and bias network which includes R5, R17, and R18.

The E/O receiver has a shield assembly, as indicated by the dashed lines in the schematic, used to minimize the amount of crosstalk between nearby receivers and between the preamplifier and output sections of the receiver.

The output of the receiver is then routed to the DEMUX logic for conversion into the signals going to the computer or to the A-7 avionics assembly, depending on the direction of the transmission. Both the E/O driver and receiver circuits are mounted on a two-sided PC board bonded to a standard 4 π page frame. The device connector has the LED or PD mounted inside it so that light can be coupled to or from the FO cable.

The IBM 4 π packaging, employed in the ALOFT system, is similar to that employed in the NWDS computer. This type of packaging was chosen due to its proven reliability and maintainability in military applications. The basic module of the 4 π technology consists of a pluggable electronic assembly, called a page, which is shown in Figure A-6. A page consists of two multilayer printed circuit boards bonded to a metal frame. The low-density page used in the ALOFT system can accommodate up to 48 integrated circuits DIP flat packs on each side of the board for a total of 96 per page. The two sides of the page are differentiated by referring to them as either A or B side. An A with an arrow is stenciled on the header to readily identify the A side of the board.

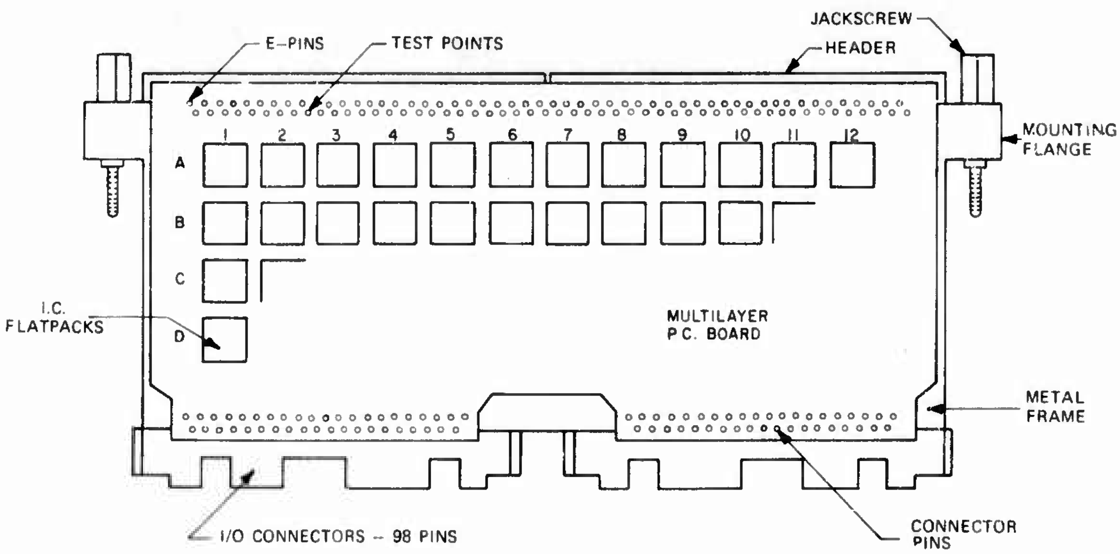


FIGURE A-6. 4 π Page.

AREA ADAPTERS

The ALOFT hardware is packaged in six adapters. Five are external to the computer and one is internal to it. The five adapters that are external to the computer are very similar in construction. They consist of the necessary logic and E/O pages, power supplies, and I/O harnesses. All are packaged in the 4 π pages described earlier. The metal frame of the page serves as a mount for the I/O connector, the power connector, and FO connectors. The adapters all have four connectors (one I/O connector, one power connector, and two FO connectors), except for the cockpit area adapter which has five. The photograph in Figure A-7 illustrates a typical 4 π page.

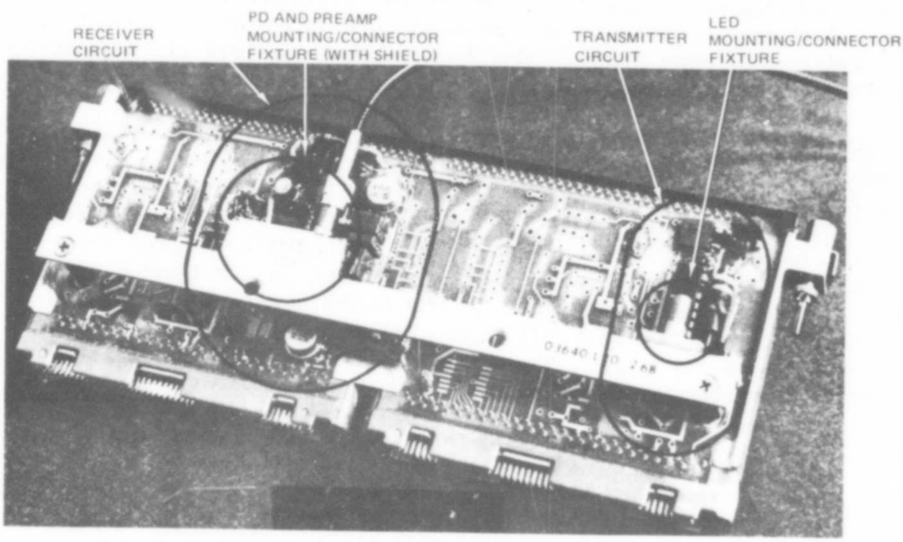


FIGURE A-7. LED and Detector Mounting on Transmitter/Receiver Circuit Board Used in ALOFT Area Adapters.

As mentioned earlier, the external area adapters are very similar to each other in the components they contain and the function they serve. For the purpose of illustration, the left-hand equipment compartment area adapter is discussed in detail here.

Figure A-8 shows the logic schematic for the A side of the page. The left-hand adapter uses two pages for its multiplexing, demultiplexing, and E/O functions. The page at location A1 on the back panel is the MUX/DEMUX or logic page. On the A side of this page is the Manchester decoder, control logic, and output buffer registers for the adapter, as well as the output drivers. The B side of the page (Figure A-9) has all the receiver logic for signals from the IMS and master function switch. Along with these are a series of sample and hold circuits, for the IMS velocity pulses, made up of integrated circuits (ICs) E4, E5, F4, F5, G5, and G6 as well as the shift registers used to serialize the data back to the computer.

The A1 page is split up so that the adapter outputs come from the A side of the page whereas the adapter inputs go to the B side of the page, thereby making it easier to pinpoint the area to be probed in case of suspected input or output problems. Figure A-10 is the timing diagram for the left-hand equipment compartment area adapter.

The E/O driver and receiver in the left-hand equipment area adapter are on page A2 of the adapter (see schematic in Figure A-11).

COMPUTER E/O ADAPTER

The NWDC E/O is central to the operation of the computer in either a COPPER or FIBER OPTIC mode.

In the COPPER mode, the E/O adapter provides the timing clock (10 MHz) and the power on reset signal to the TC-2A converter logic control and timing page. Moreover, it also provides the necessary jumper so that the I/O signals that are routed to the adapter can go back out to their corresponding I/O pins.

When in a FIBER OPTIC mode, the E/O adapter provides all of the MUX/DEMUX capability for the NWDC I/O signals as well as the Manchester-encoding E/O conversion and required control and timing necessary for communication to all of the external unit and area E/O adapters.

The NWDC E/O adapter consists of a back panel assembly that holds the needed logic and E/O pages and I/O harness. This back panel assembly is of the same type as was used in the other E/O adapters except that it has eight usable page locations. A ninth location on the back panel, which has no page I/O connectors, is used to hold the A9 harness page that goes to the computer I/O connectors when the computer is in a FIBER OPTIC mode, thereby disconnecting all the ALOFT system signals from the computer I/O.

A block diagram of the E/O adapter is shown in Figure A-12 depicting the adapter as it appears in the FIBER OPTIC mode. This diagram shows the page locations and general arrangement of the adapter.

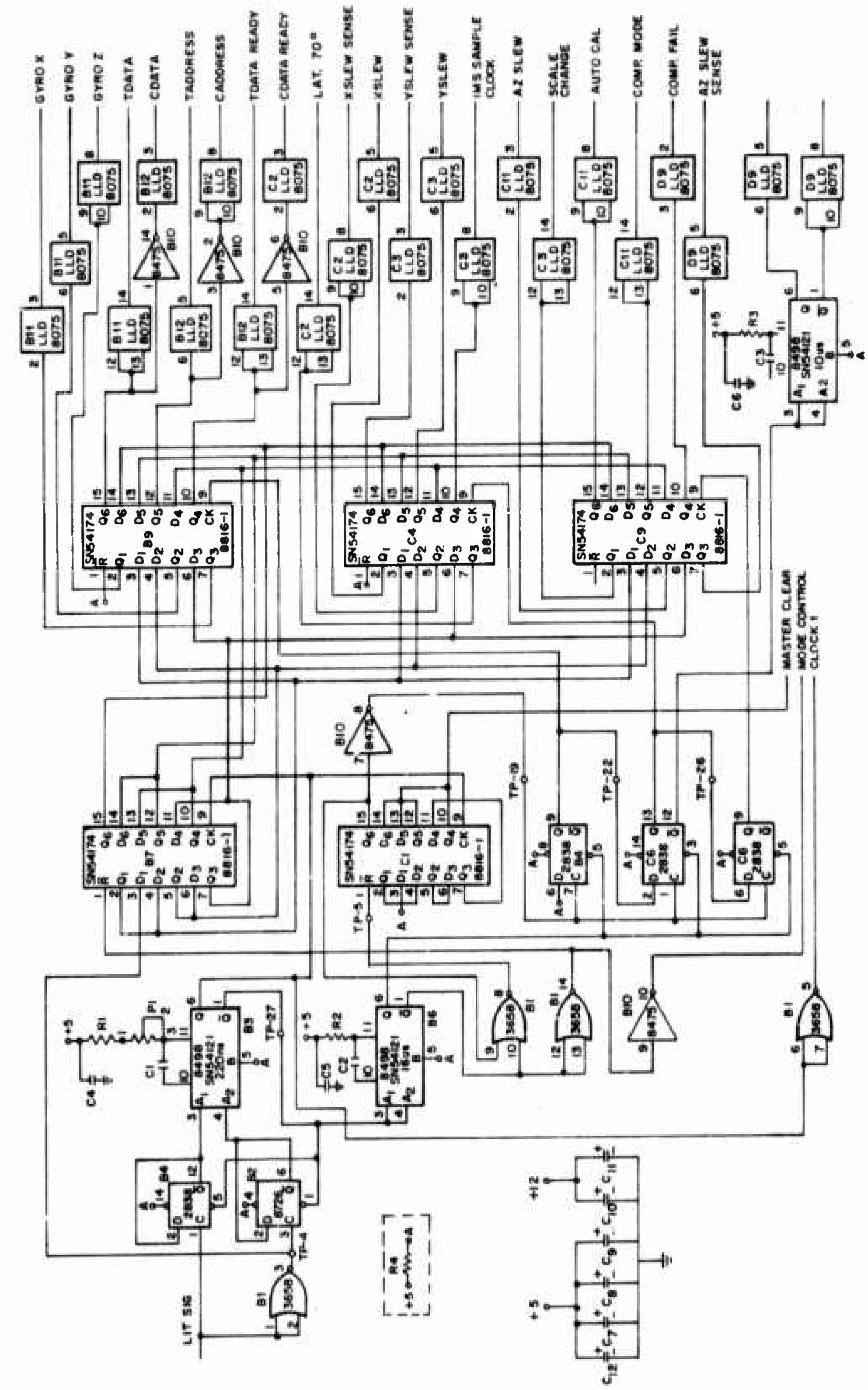


FIGURE A-8. Left Bay Adapter E/O Logic, Side A.

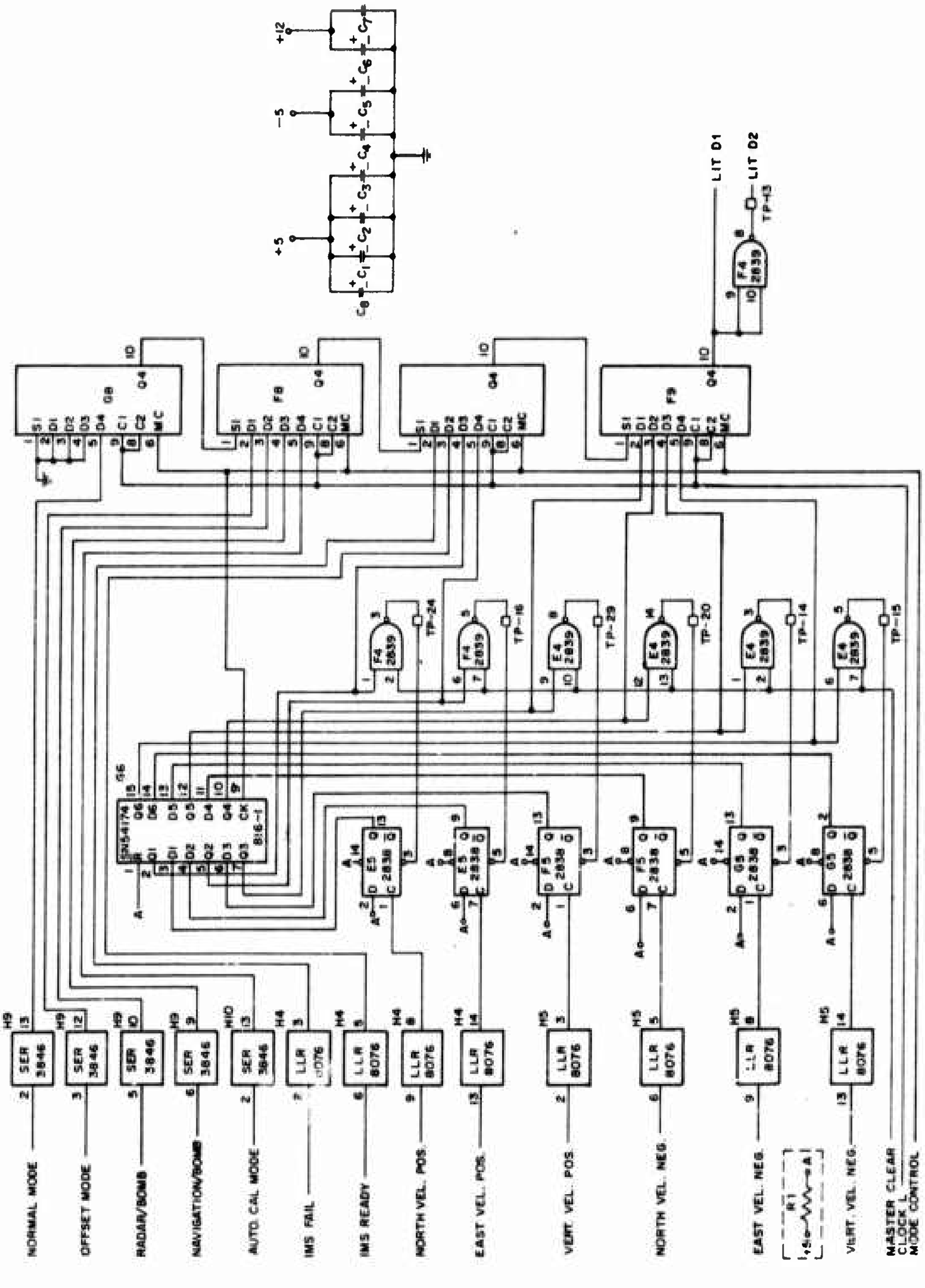


FIGURE A-9. Left Bay Adapter E/O Logic, Side B.

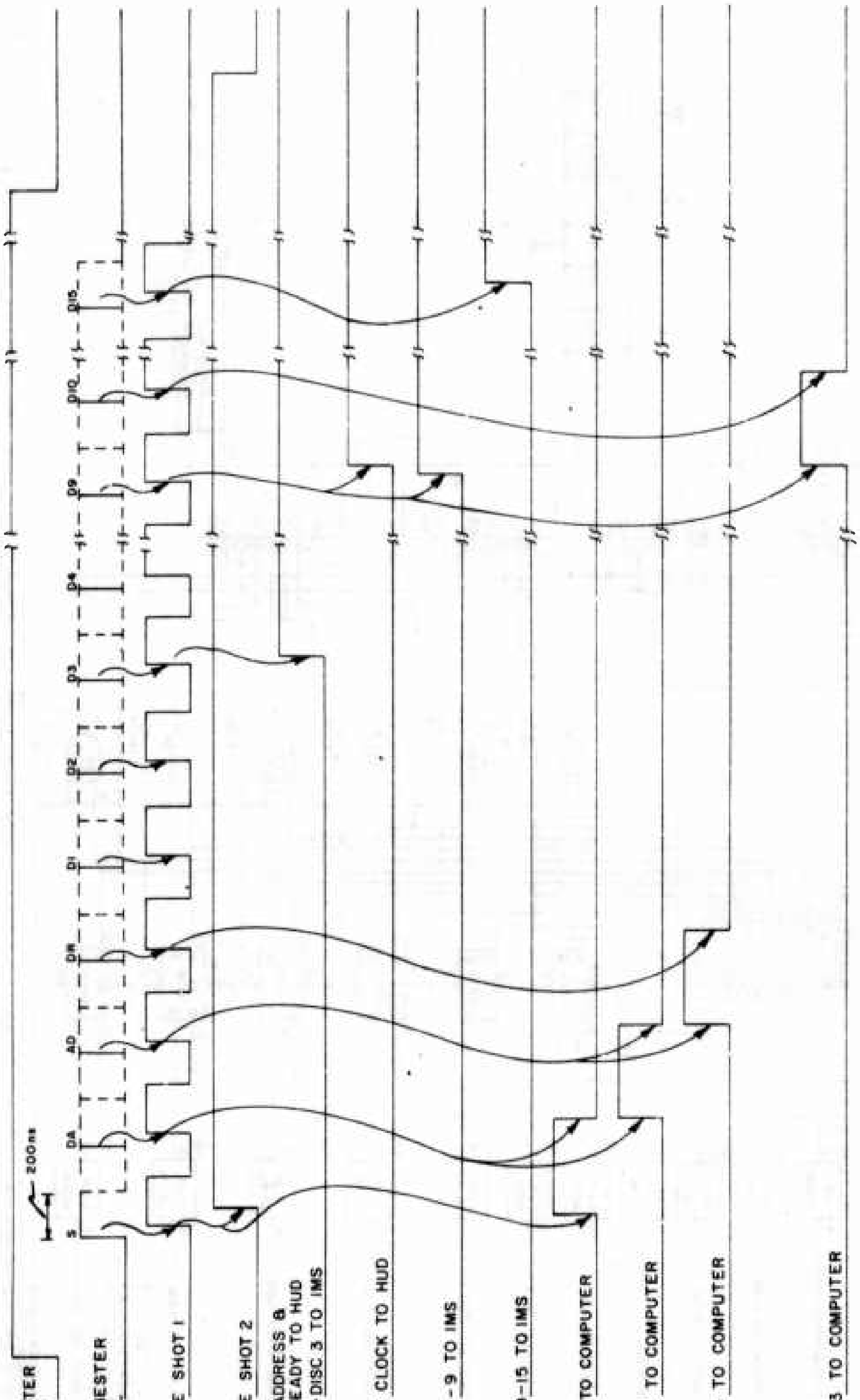


FIGURE A-10. Left Bay Adapter Logic Timing.

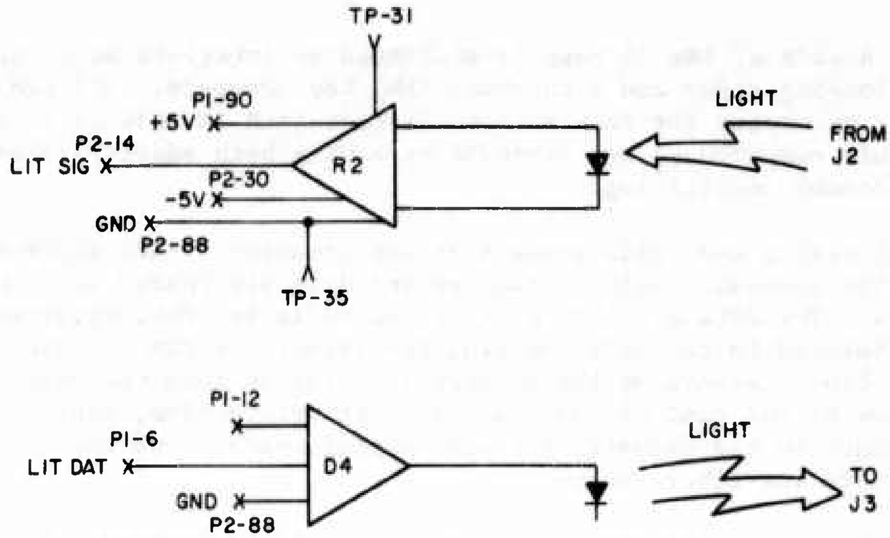


FIGURE A-11. Schematic of Left-Hand Area Adapter E/O Functions.

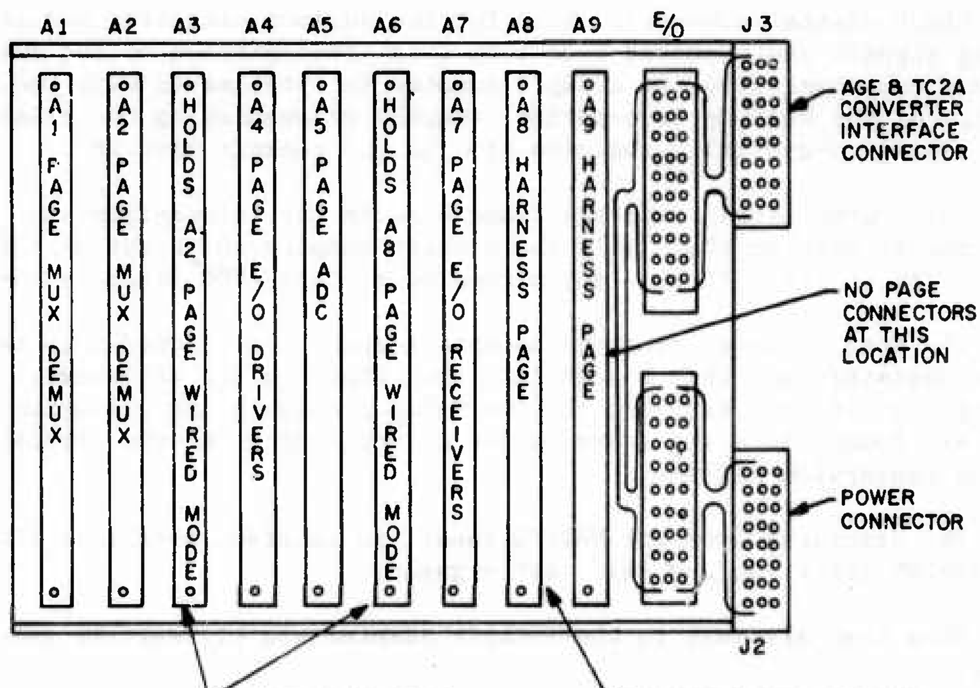


FIGURE A-12. Arrangement of Pages in E/O Adapter.

A1 Page

The A side of the A1 page is dedicated to interface with the forward-looking radar and right-hand (RH) bay adapters. All the circuitry necessary for this purpose is contained in this half of the page. This compactness was achieved by having both adapter interfaces share a common control logic.

With rising and falling edges of the computer 50-kHz clock trigger signal, the transmit logic is enabled and data are loaded into the shift registers. The data are then shifted out serially, Manchester-encoded, and transmitted to the corresponding E/O drivers on the A3 page. Inputs from the E/O receivers on the A7 page are clocked into the output buffer flip-flops by the control logic at the appropriate time, thereby generating inputs to the computer for each signal coming from the FLR and doppler sets via fiber optics.

The B side of the page contains all the logic necessary to transmit information to and receive information from the cockpit area adapter over the 28-VDC discrete channel. For this application, a computer 50-kHz serial clock is received and counted down for use as trigger for data transmission and reception.

Since digital conversion bits for the Bullpup elevation and azimuth analog signals are received over this link, transmission of the discrete signals that come from the cockpit adapter is interleaved with the transmission of the Bullpup information, thereby accommodating the relatively slow analog-to-digital conversion time in the cockpit adapter.

The control logic sets two frame bits in the information sent to the cockpit adapter that tells the cockpit adapter which set of information it is to transmit at a given time over the 28-VDC discrete channel.

The data received from the cockpit adapter are clocked into two input registers and then loaded into the output buffer registers. When conversion bits are received for the Bullpup azimuth and elevation bits, they are loaded into registers on the A5 page which has the digital-to-analog conversion modules.

Two discretes from the NAV/WD panel are received over this link, the NAV/WD interrupt and self-test signals.

Data that are sent to the cockpit adapter are transmitted every frame.

A2 Page

This page is the other MUX/DEMUX that performs logic and MUX/DEMUX functions in the computer E/O adapter.

On the A side of the page is the logic that interfaces with both the left-hand (LH) bay and ASCU adapters. With every positive transition of the computer's 50-kHz serial output clock, data are sent to and received from these adapters.

Even though the transmission to the left bay adapter contains information on 15 different discrete signals and the serial channel to HUD electronics unit while only two discretes are transmitted to the ASCU adapter, the sharing of common timing and control logic for both adapters enables reception of the 13 signals coming from the left bay adapter and the 17 signals from the ASCU adapter with a minimum of hardware.

Serial data going to the adapters are Manchester-encoded prior to transmission to the E/O drivers, as is the case with all the digital optical links coming from the computer E/O adapter.

Information being received from the left bay and ASCU adapters is shifted into an input register and then loaded into the appropriate buffer register, thereby performing the needed serial-to-parallel conversion.

Contained on the B side of the page is the logic that interfaces with the optical transmission and reception of the serial and control signals to/from the navigation and weapons delivery control panel.

Since this interface is program controlled, transmission is affected whenever the computer raises either the read or write lines. The logic then starts transmission by sending a burst of pulses containing the necessary control information, i.e., address information and whether the operation is read or write. This initial burst is followed by 16 other bursts coinciding with transitions of the computer 1-MHz serial clock. These are on the A2 page.

A4 Page

This page contains the six digital E/O drivers that transmit the optical signals to the external E/O adapters. Only the A side of the page was used for this purpose.

When installed, this page has a bracket mounted over it that serves to tie down the computer's internal fiber optic cables that go to the E/O drivers. The bracket is held in place by two screws mounted into the page jackscrews.

A hex inverter integrated circuit (IC) on this page provides buffer drive for certain of the signals going to the aerospace ground equipment (AGE) connector. These signals, which are outputs and inputs to the MUX/DEMUX logic, are routed to the AGE connector for test and trouble-shooting purposes.

A5 Page

The A5 page of the computer adapter is identical on both A and B sides. Each side has an analog-to-digital converter module along with two 6-bit registers mounted on it.

The A side of the page is used for the conversion of the digital bits for the Bullpup azimuth signal back into its proper analog format before it goes to the TC-2A signal converter. The B side of the page is used to convert the Bullpup elevation signal back to analog form.

The converter modules run continuously changing the analog value as the data in the register changes. All 12 digital bits and the clock signal that loads the registers come from the DEMUX logic on the B side of the A1 page.

This page is installed only in the FO mode of operation.

A7 Page

The A7 page, normally referred to as the 6-receiver page, contains all six of the E/O receivers in the computer adapter as well as the direct analog transmitter.

The A side of the page has on it the receivers for the optical signals from the ASCU, left bay, and FLR adapters.

The B side of the page has the E/O receivers for signals from the right bay and cockpit adapters.

After the optical signals are converted to electrical signals by the receivers, they are sent to the appropriate MUX/DEMUX logic, where the serial signal is changed to parallel form.

The direct analog driver has the distinct characteristic of containing two LEDs and a PD. One of the LEDs is used for the signal output; the other, together with the PD is used as an optical feedback loop for temperature compensation. Both LEDs are mounted in the same connector block, thereby providing temperature tracking. Since this circuit provides a light output that is directly proportional to the electrical input signal, it should be adjusted to its proper output prior to aircraft usage.

Harness Pages A8 and A9

The other two pages that are used in the computer E/O adapter are the two harness pages labeled A8 and A9. These two pages are made up of a modified 4 π page frame, on which are mounted the standard page I/O connectors and two narrow PC boards with plated-through holes that are connected one-for-one to the page I/O pins. Harness wires are soldered into the holes. As a result, the harness wire can be connected to the back panel assembly by installing the harness page.

It is the use of these two harness pages that provides the capability for the ALOFT to be used in either a fiber optic or wired mode.

When the computer is in a COPPER mode, harness page A8 is plugged into location A6 on the back panel and harness page A9 into location A8. Jumpers are wire-wrapped on the back panel between locations A6 and A8 so that when the pages are in these locations, the corresponding wires are jumped together. The other end of the harness, soldered into the A8 page, goes back to the computer back panel. The wires that are soldered into the A9 harness page go back to the computer I/O connectors. When the harness pages are in locations A6 and A8, the computer has an external I/O that is the same as it was prior to modification.

For a FIBER OPTIC mode of operation, the A8 harness page is installed in location A8 and the A9 harness page in location A9. Since location A9 has no page I/O receptacles, the ALOFT system signals are disconnected from the computer I/O. The A8 harness page carries these signals, between the E/O adapter and the computer back panel, that are transmitted or received via fiber optics.

NAVIGATION AND WEAPONS DELIVERY COMPUTER

Due to space limitations in the A-7 aircraft, a tactical computer was modified internally to accommodate an E/O adapter. The modification to the computer was twofold. Space had to be made for the E/O adapter and provisions made to allow the adapter to interface with the computer and optically with the external unit and area adapters.

The solution involved the removal of the Kearfott signal converter that is a standard part of the TC-2 computer. The converter was replaced with the IBM-built signal converter that is employed in the TC-2A computer. This converter uses one-half the space that the Kearfott converter does, while performing the same signal conversion functions. This computer thus modified is referred to as the ALOFT computer.

In order to facilitate the testing and maintenance of the ALOFT computer (with the TC-2A signal converter) and still use existing test

facilities, the computer was designed with a convertible feature. The ALOFT computer can be connected by either the COPPER wired mode or the ALOFT system optical mode.

When the computer is in its COPPER configuration, it presents the same I/O to the aircraft avionics as it did prior to modification. Although converting the computer takes about 2 hours, the capability to operate in either mode was greatly desirable not only for maintenance and troubleshooting purposes, but also because it provides the means to establish a reference for the performance of the ALOFT system hardware.

TC-2A Converter

The use of the TC-2A signal and data converter, in the TC-2 computer for the ALOFT program, provided the room needed to incorporate the computer E/O adapter within the computer frame.

The TC-2A converter is made up of a back panel and side-rail structure that holds four logic and analog circuitry pages as well as seven Scott-T transformers mounted on a bracket. These are used to derive digital information from various analog and synchronization signals. This converter thereby replaces the Kearfott unit that is a part of the unmodified TC-2 computer.

The converter back panel is hard-wired; that is, all interconnections are made by internal layers on the back panel. In the TC-2A, however, this back panel is larger and holds the I/O and CPU portions of the TC-2A computer as well. As a result, various connections had to be added to this back panel via soft wires.

The operation of the converter is outside the scope of this report. For information on it, one should refer to the appropriate sections in TC-2A operations and maintenance manuals.

COMPUTER MODE CONVERSION

The modification to the TC-2 computer used in the ALOFT program was done so that it is possible to convert the computer from a fiber optic mode of operation to a wired mode of operation and vice versa.

Due to packaging limitations, conversion from one mode to the other must be done in a proper sequence.

Fiber Optic Mode to Wired Mode Conversion

To convert the computer from the fiber optic mode to the wired mode, the computer must first be entirely disconnected from any installation it might be in. The conversion involves 30 steps as follow:

1. Place the computer on its side so that the side plate, which allows access to the converter and E/O adapter (right-side cover plate looking at the computer from the front), is up.

2. Remove the right-side cover plate.

3. Disconnect all the Winchester connectors P1-P5 at the I/O end of the TC-2A converter.

4. Disconnect both Winchester connectors on the E/O adapter.

5. Remove the TC-2A converter A9 page.

6. Remove the converter A8 harness page.

7. Remove the ground wires for the AGE harness and the A8 and A9 harness pages of the E/O adapter.

8. Drape the AGE harness out of the computer.

9. Unscrew the allen-head screws from the top and bottom of the computer that hold the converter assembly in place.

10. Carefully remove the converter assembly from the computer.

11. Cut the lacing that ties down the fiber optic cables to the top of the converter A4 and A7 pages and remove the tie-down brackets from the top of both pages.

12. Remove the A4 six-driver page and carefully disconnect all the FO cables from the LIT device connectors. Store the A4 page.

13. Remove the A7 six-receiver page and carefully disconnect all the FO cables from the LIT device connectors.

14. Remove pages A1, A2, and A5 from the E/O adapter; store the A1 and A5 pages.

15. Reinstall the A2, L20-304-page in the A3 location.

CAUTION

If this page is left in the A2 location for wired mode operation, serious damage to the computer and NAV/WD panel I/O can result.

16. Remove both harness pages A8 and A9 from their places at locations A8 and A9.

17. Carefully free the FO cables from under the brackets that hold connectors J2 and J3 on the E/O adapter.

18. Remove the four screws that hold the computer FO, multipin connector J10 in place.

19. Carefully remove connector J10 with its FO harness from the computer. Store it.

20. Install harness page A8 in location A6.

21. Install harness page A9 in location A8.

22. Replace the TC-2A converter in the computer; tighten down the allen-head screws that hold in place. (Alignment is difficult.)

23. Reconnect connectors P1-P5.

24. Place the AGE harness back in its place, making sure to tuck it in well behind the E/O adapter side rails.

25. Screw in the ground wires for the AGE harness and harness pages A8 and A9.

26. Install the AGE harness page A8 in its location in the TC-2A converter.

27. Reconnect connectors P2 and P3 (located between the E/O adapter and signal converter), making sure to tuck the power harness going to connector P3 behind the side rail of the converter assembly.

28. Reinstall the converter A9 page.

29. Replace the computer side cover plate.

30. Cover the hole left by connector J10 with masking tape or other appropriate material.

The computer is now ready for wired mode operation and can be used in a rack as any other TC-2.

Wired to Fiber Optic Mode Conversion

To convert the computer from wired to fiber optic mode, first follow the instructions for the fiber optic to wired conversion, up to and including step 10 of the procedure. At this point, the converter is out of the computer and the AGE harness is draped out of the way. Proceed with the additional 22 steps of the conversion as follows:

1. Remove page L20-304 from its position in location A3 and reinstall at location A2.

2. Remove harness pages A8 and A9 from their positions at locations A8 and A9.

3. Carefully reinstall the FO connector into location J10, making sure to replace all four screws that secure it in place.

4. Separate the FO cables from connector J10 into two bundles. Cables marked 30, 21, 20, 16, 34, and 7 are routed under the E/O adapter J3 connector. Drape the cables out of the way.

5. Install harness pages A8 and A9 into the E/O adapter A8 and A9 locations, respectively.

6. Install the A1, L20-297 page.

7. Install the A5, L20-302 page.

8. Carefully connect the appropriate FO cables to the receivers and driver on the A7, L20-294.

9. Install the A7 page in the E/O adapter.

10. Connect remaining FO cables to the appropriate drivers on the A4, L20-815 page.

11. Install the A4 page in the E/O adapter.

12. Install the FO cable tie-down brackets over the top of the A4 and A7 pages.

13. Tie down the FO cables to the brackets using regular harness lacing.

14. Carefully arrange the FO cables portion that goes under the TC-2A converter so that the cables lie flat.

15. Replace the TC-2A converter assembly into the computer, ensuring all of the allen-head screws that hold it in place are installed.

16. Reconnect connectors P1-P5.

17. Bring in the AGE harness into the computer and tuck both legs of the harness behind the E/O adapter side rails.

18. Install the AGE harness A8 harness page into location A8 on the TC-2A converter back panel.

19. Reconnect connectors P2 and P3 on the E/O adapter, making sure the harness that goes to P2 is tucked behind the converter side rail.

20. Secure ground wires for the A8 and A9 harness pages and the AGE connector harness to the most convenient page jackscrew.

21. Reinstall the converter A9 page.

22. Replace the computer side cover plate.

The computer is now ready for fiber optic operation.

Appendix B

DETAILED INSTALLATION DESCRIPTION

The following paragraphs and illustrations relate how the test aircraft was modified for the ALOFT system.

Figure B-1 details the routing of the wiring harness and fiber cables; the asterisks (*) show the locations of holes that were drilled in the aircraft to accommodate them.

The Right Avionics Compartment Area Adapter was installed on the right avionics compartment shelf immediately forward of the air data computer (ADC). Three holes were drilled in the shelf for installation of the mounting plate assembly. The area adapter box was then secured to the mounting plate and properly grounded. Figure B-2 shows the adapter location.

The Left Avionics Compartment Area Adapter was mounted in the space provided for the LORAN on the left avionics floor. The three existing fastener locations were utilized and one additional hole was required to be drilled through the floor in order to secure the mounting plate. The ground strap on the area adapter was attached and the adapter was mounted to the plate.

The ASCU Adapter Box was mounted on the left avionics compartment shelf immediately forward of the ASCU. Three additional holes were drilled in the shelf to mount the mounting plate. The grounded ASCU adapter box was then mounted to the plate. Figure B-3 details the left bay area adapter location for both the ASCU adapter and the left bay area adapter box.

The FLR Adapter Box was mounted in the forward left mid-equipment compartment, outboard of the sweep generator. The adapter box was attached to the existing aircraft structure using a plate, brackets, and clips. It was necessary to drill five holes through the mounting plate and the mounting bracket at the same time because of the close tolerances on the holes. Care was taken to properly ground the adapter box, and then plate and assembly were installed in the aircraft. Figure B-4 shows the location of the FLR adapter box in the forward left mid-equipment compartment.

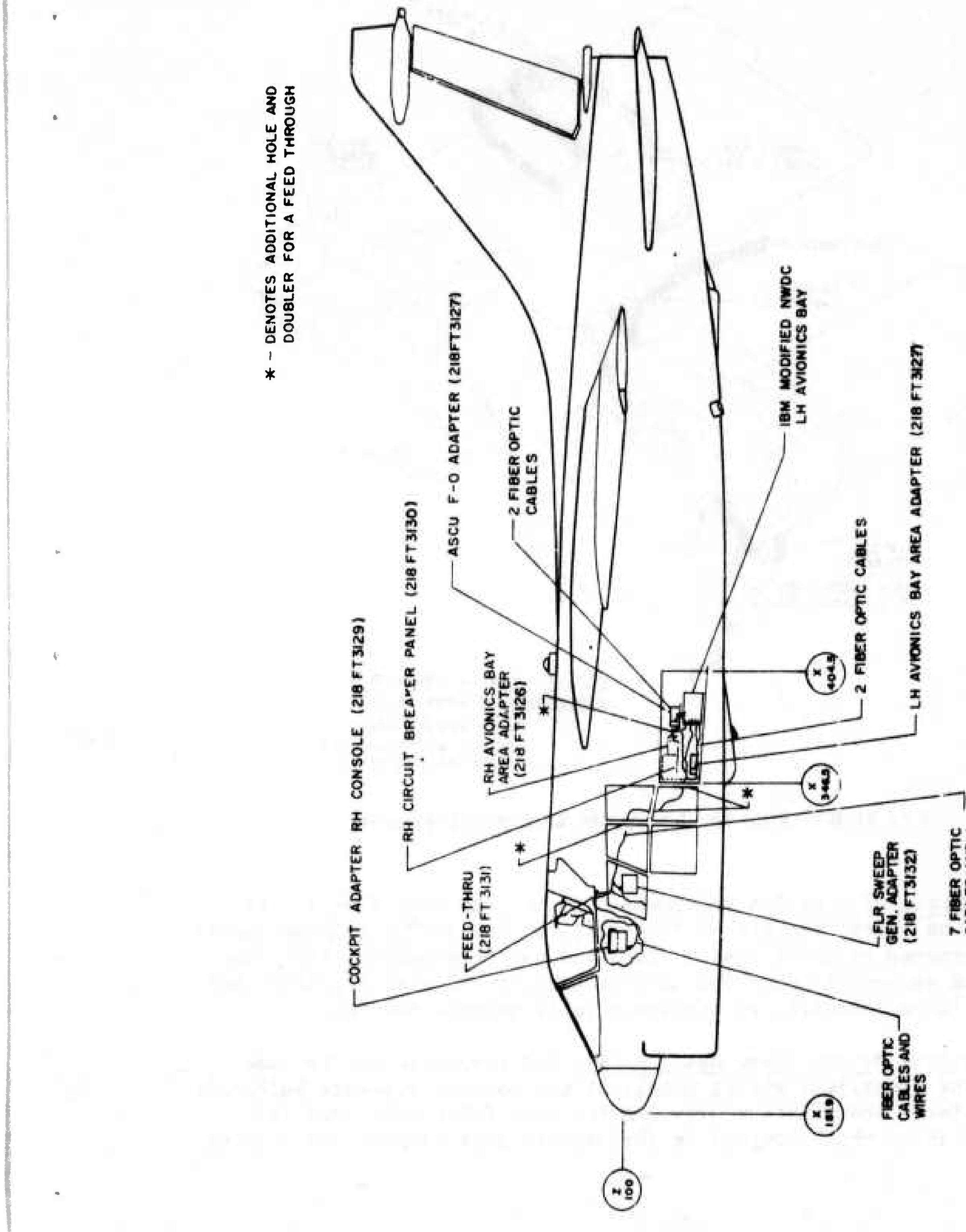


FIGURE B-1. Aircraft Modification Layout.

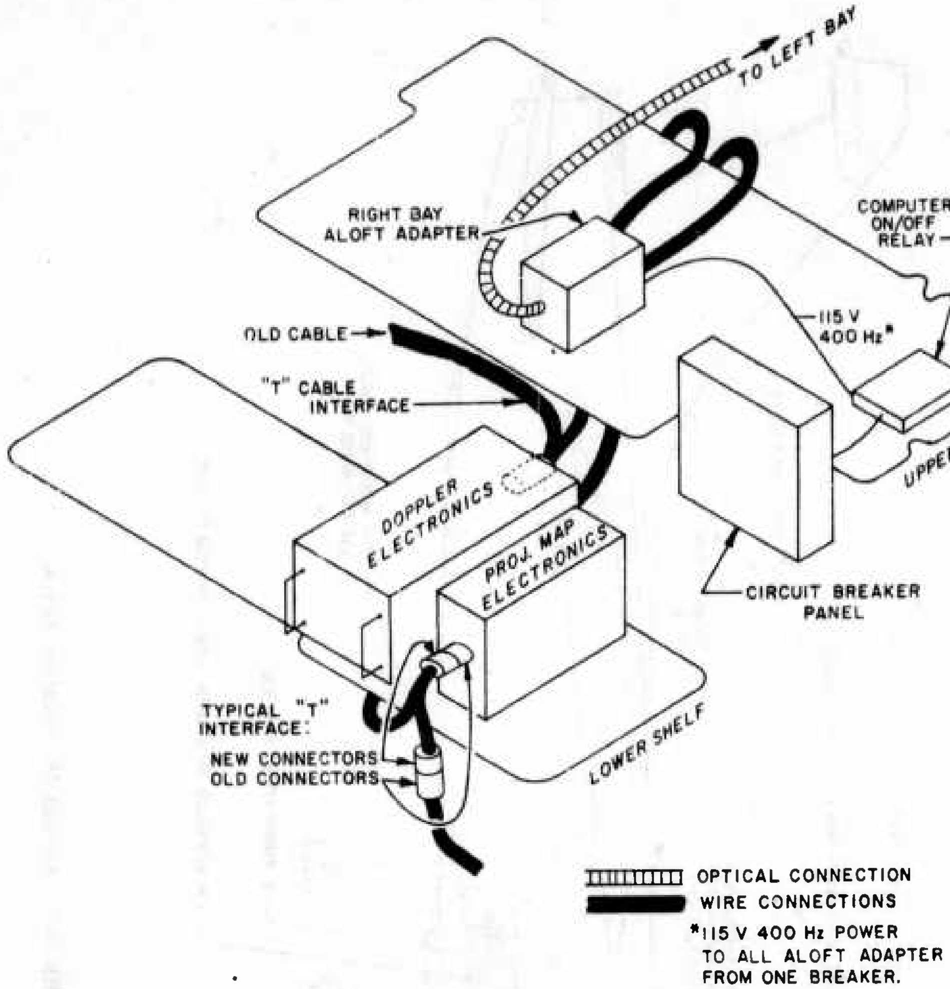


FIGURE B-2. Right Bay Area Adapter Location and Mounting.

The Cockpit Adapter Box was mounted in the map case slot in the right-hand instrument console of the cockpit. The canopy release handle had to be removed prior to installation and was reinstalled after the installation was completed. The cockpit adapter box also required that a heat shield be installed to environmentally protect the box.

The routing of the fiber optic cables was completed in the same manner as the electrical wiring except at the cockpit pressure bulkhead. This feedthrough installation provides for five fiber optic and four electrical cables which connect to the cockpit area adapter box. There

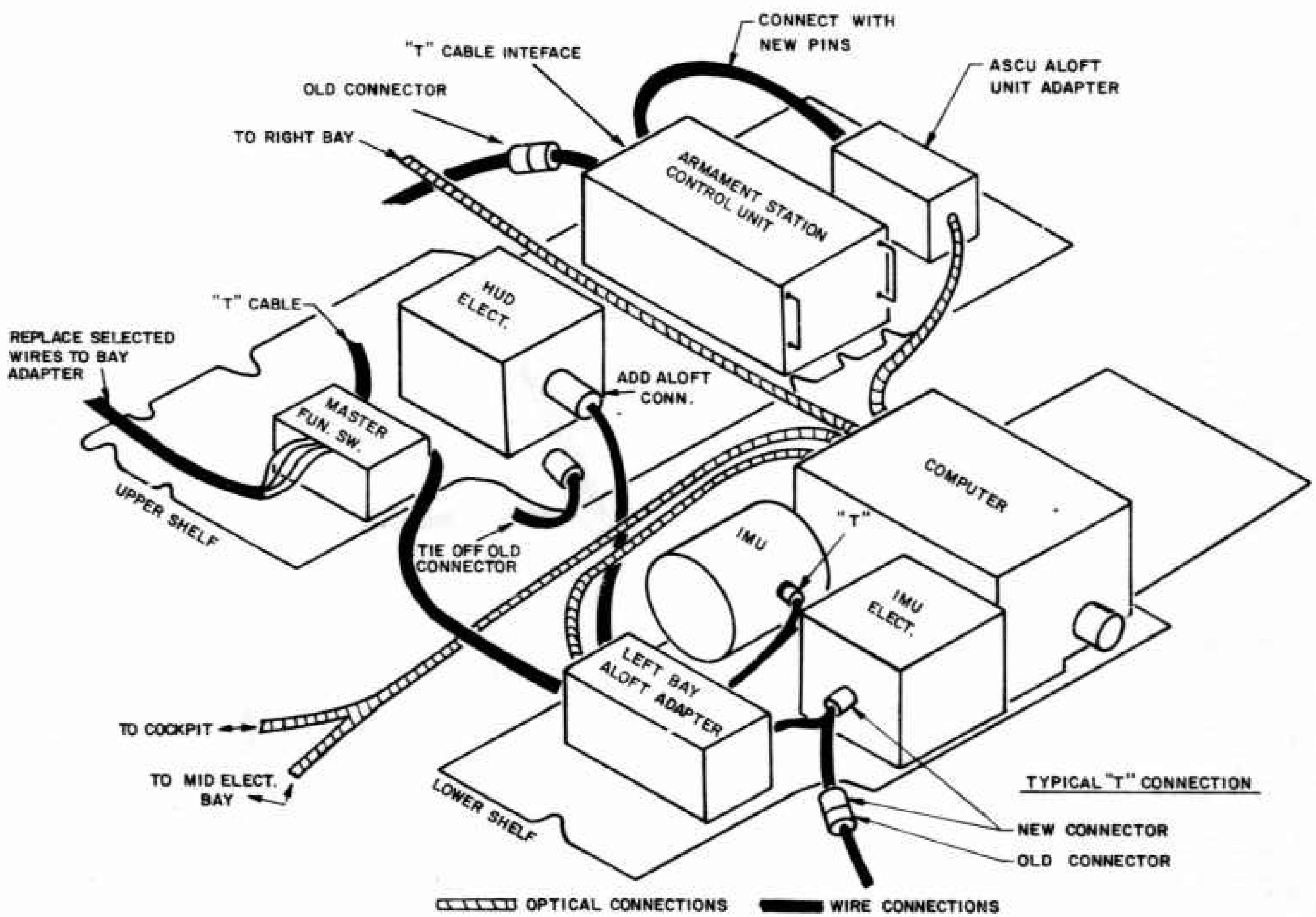


FIGURE B-3. Left Bay Area Adapters Location and Mounting.

were five penetrations required for fiber optic cables and wiring in addition to the one described above; where possible, the fiber optic cable and wiring was routed together. Doublers were required to reinforce holes drilled in aircraft structure for routing. All electrical installations were made in accordance with MIL-W-5088; however, in critical areas, safety of flight was the prime consideration for all installations.

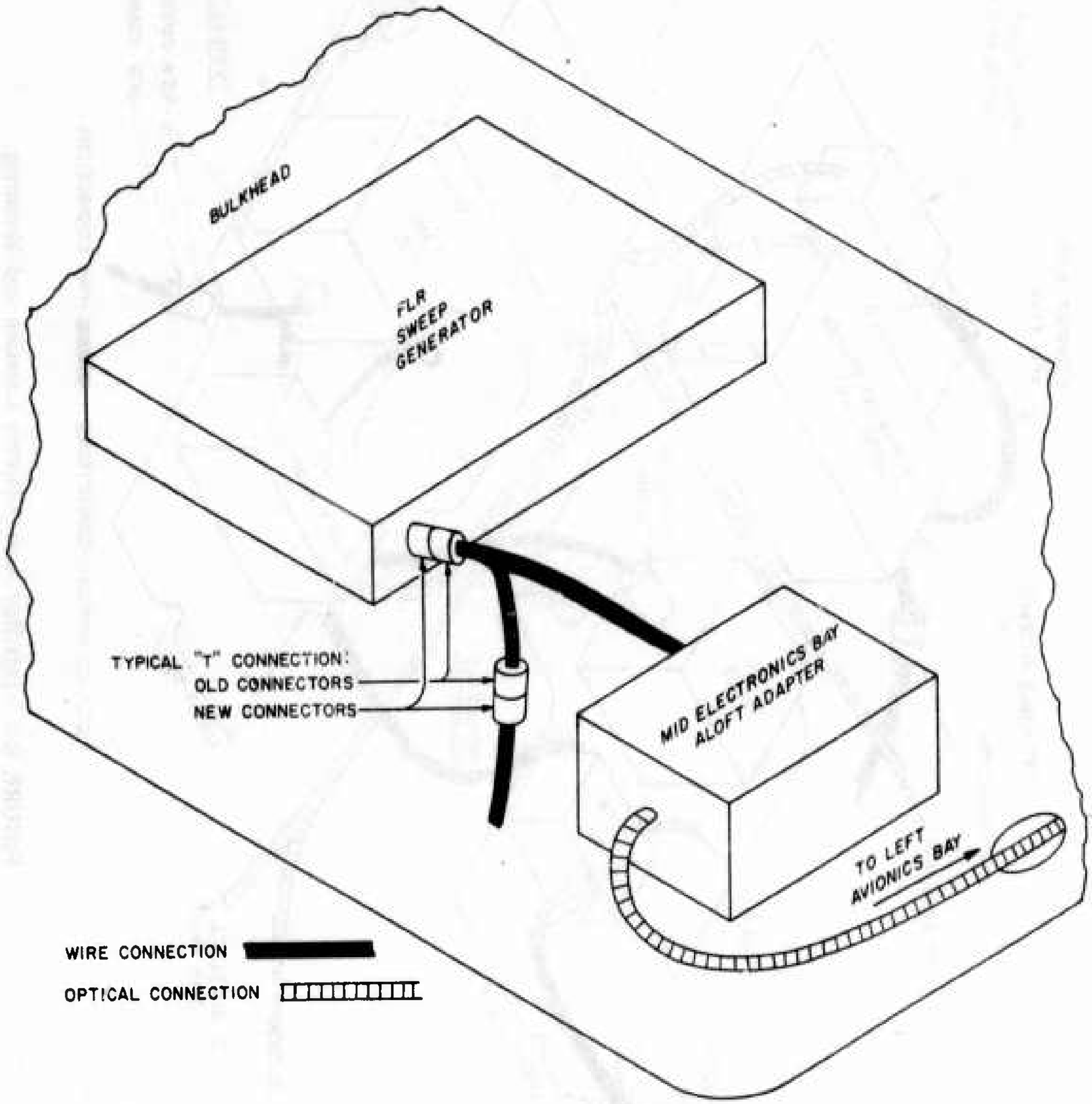


FIGURE B-4. FLR Adapter Box Location and Mounting.

Appendix C
TEST REQUIREMENTS

PREDEMONSTRATION VALIDATION

The predemonstration validation is based upon the objectives of the ALOFT program and includes a cursory validation of the OFP using a simulator, selected ground tests, performance of the OTP, and various navigation and radar grooming flights. The specific tasks pertaining to the predemonstration validation, the aircraft configuration to which they are applicable, and the test where each will be performed are listed in Table C-1.

TABLE C-1. Predemonstration Validation Requirements.

Task \ Test	FLEET		ALOFT/COPPER		ALOFT/FIBER OPTIC	
	Lab.	A/C	Lab.	A/C	Lab.	A/C
Boresight		X				
OFT:						
FLEET		X				
ALOFT			X	X	X	X
Cursory validation			X		X	
System test		X	X		X	X
IMS drift check		X	X	X		X
Project test		X	X			X
Grooming flights (navigation and radar evaluation)		X		X		X

Boresighting

Special tools and test equipment were required to accomplish this portion of the effort: a 216-00275 short-range boresight tool and a 215-00112-28 AOA vane alignment set. The boresighting was accomplished in accordance with the procedures contained in NAVAIR 01-45AAE-2-14.

System data-point information was recorded for each of the equipments that required boresighting. The boresight target and a detail of tolerance adjustments for each equipment are shown in Figures C-1 through C-4 for the radar mount, antenna assembly fixture, IMU mount, and the electrical equipment mount.

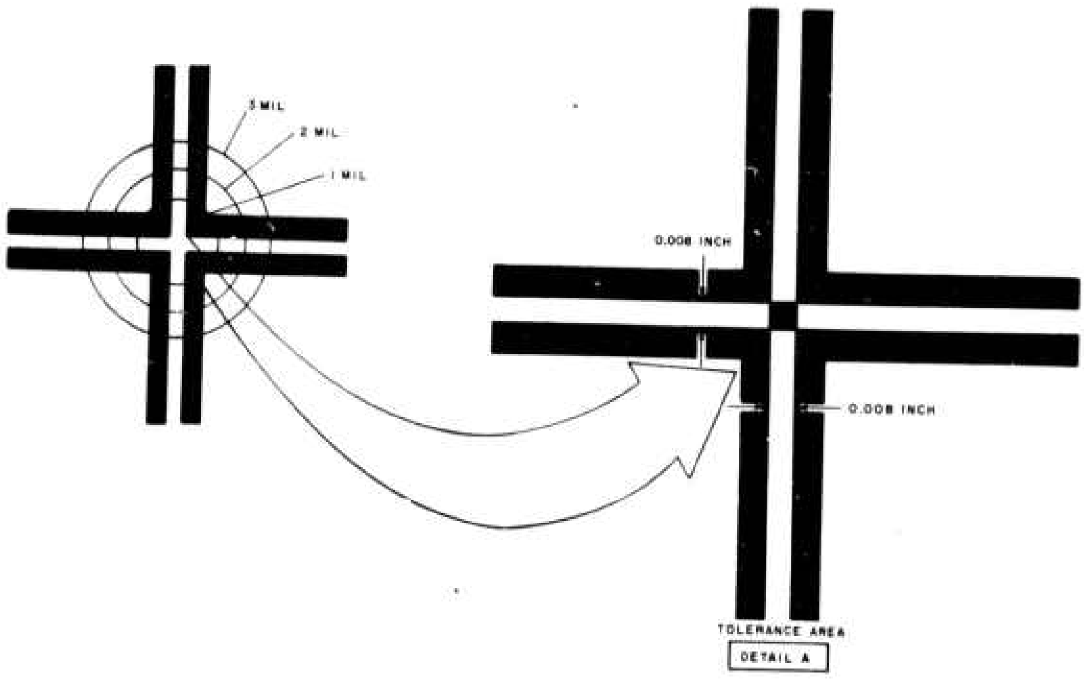


FIGURE C-1. Radar Mount Boresight Tolerance.

Operational Test Program

The OTP is a special software tool designed to conditionally check the compatibility of the computer with all other avionic subsystems. The ground checks made with the OTP were in accordance with NAVAIR 01-45AAE-2-17.6. A checklist was followed while implementing the ground checks using the OTP and contained 32 individual categories of checks. The OTP was processed in the configurations depicted in Table C-1.

Cursory Validation

The cursory validation was accomplished in the A-7 integration laboratory. Table C-1 shows that both the ALOFT/COPPER and ALOFT/FIBER OPTIC configurations underwent the validation. These evaluations consisted of navigation validation, weapon evaluation, and hardware checks.

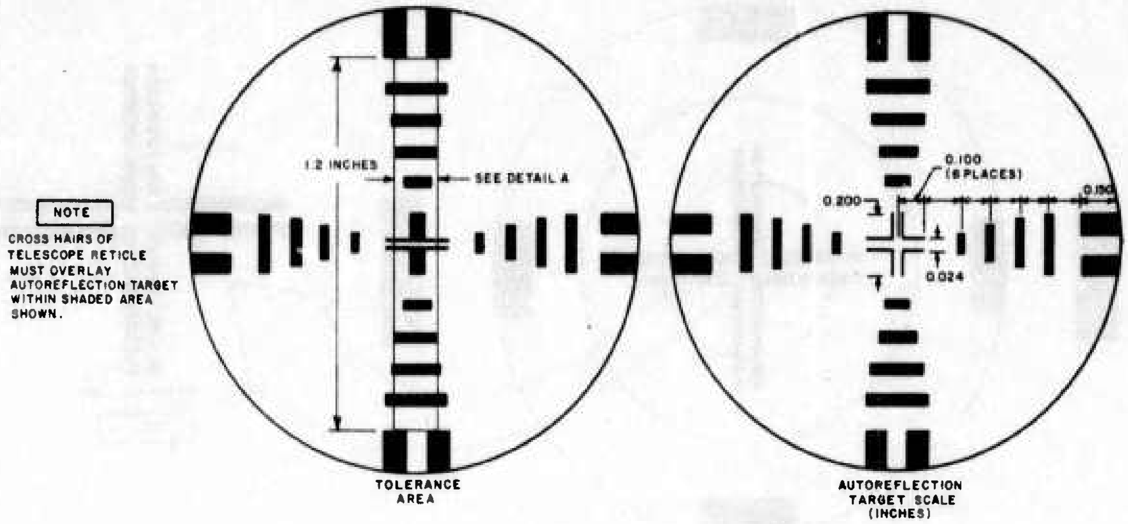


FIGURE C-2. Antenna Assembly Fixture Boresight Tolerance.

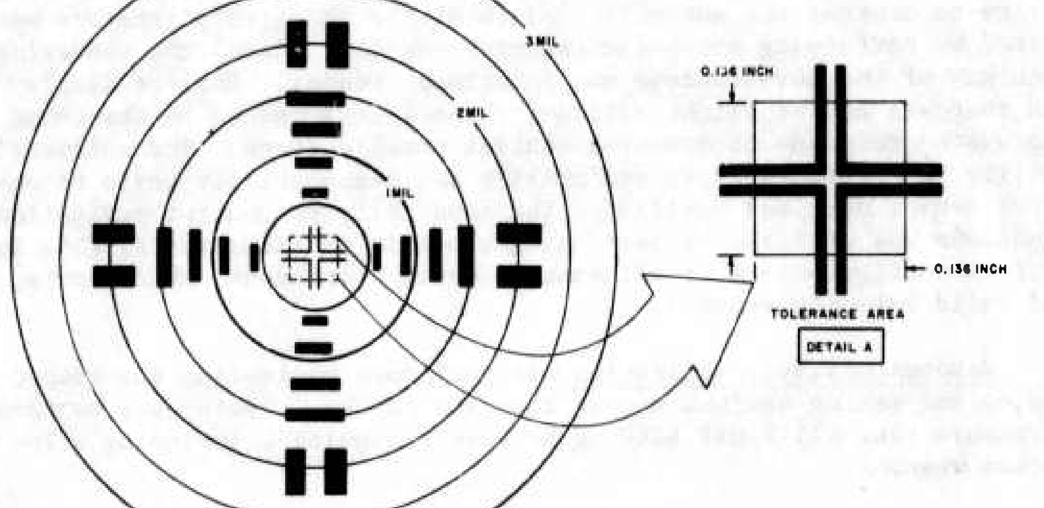


FIGURE C-3. IMU Mount Boresight Tolerance.

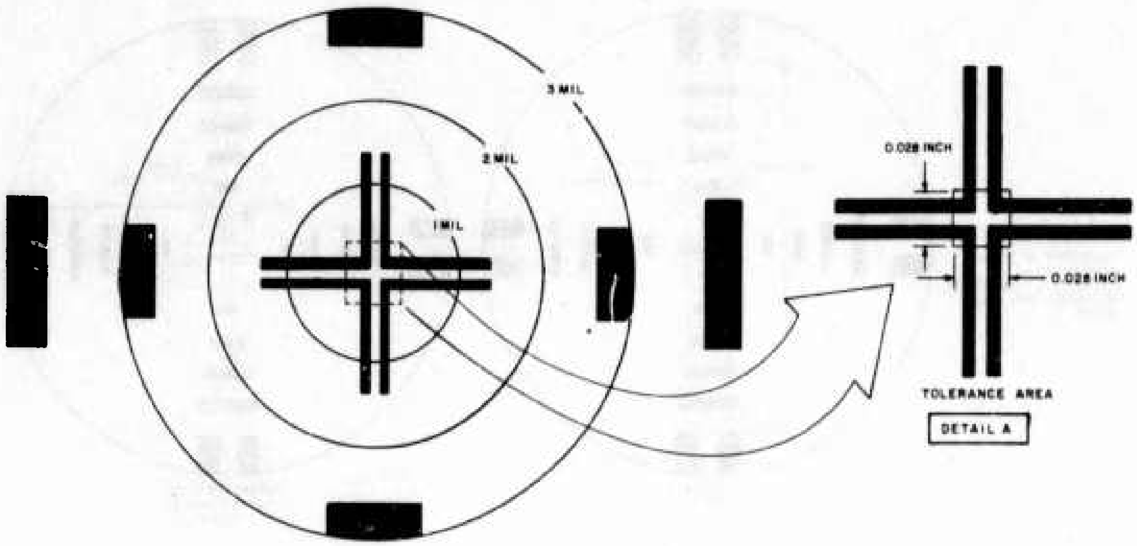


FIGURE C-4. Electrical Equipment Mount Boresight Tolerance.

Navigation validation evaluated the capability to accurately align the IMS platform tests for each alignment method. The IMS-HUD alignment mode was tested by performing a test matrix in which both the amount of platform misalignment and IMS mode selection were varied. The capability to control the automatic update of the IMS gyro parameters was tested by performing automatic calibrations (AUTO CALs) and observing the accuracy of the computations and functional moding. Correct display and readouts of the flight recorder channel were tested by observing the system response to computer control panel entries. The software's ability to correctly apply reliability and reasonability tests to the input sensor data was verified. The capability to control navigation functions was verified by performing a matrix of simulated flights for various configurations of alignments, navigation modes, wind inputs, and valid velocity sensors.

Weapons delivery validation was performed by testing the weapon moding and making various weapon accuracy checks. Tests were performed to ensure that all legal ASCU codes were recognized, including pilot-option weapons.

Interface checks evaluated the capability to interface the tactical computer with other components of the navigation and weapon delivery system and was tested using the actual hardware. These hardware checks were made in the laboratory and on the test aircraft to ensure proper fit and interface.

System checks were made in order to verify the operation and integration of the system; a special ALOFT OFP was used. The scope of these tests required the following special tools and test equipment: an AN/APM-348 radar altimeter test set, the AN/ASM-478 IMS, and doppler ground speed simulator. Performance during systems checks was carefully monitored and thoroughly analyzed to ensure system integrity. These tests were especially important because a newly configured tactical computer was used in the integration of the ALOFT system.

The IMS in-place inertial navigation check (drift check) was performed to determine if the IMS performance was within the limits required for accurate navigation and weapons delivery. The land-based IMS AUTO CAL procedure was performed to update the IMU north and east gyro parameters.

The project test included various special tests of instrumentation systems. Initially, after assignment of an aircraft to the project, a test of the flight recorder tape was made to verify accurate recorder operation. Also, a flight recorder test tape was "pulled" on each of the computer configurations to ensure that the recorder was still functioning properly after changing to each configuration.

Grooming flights (radar and navigation evaluation) are system verification flights. They were flown after the cursory validation was completed and revealed that minor adjustments needed to be made to the non-ALOFT equipment. It should be noted that any time a different set of components (e.g., avionic subsystems) is installed in a test aircraft, adjustments or calibration is required to meld the inherent idiosyncracies of the aircraft, the subsystems, and the software.

BASELINE FLIGHTS

To establish a data baseline against which the ALOFT/FIBER OPTICS configuration of the aircraft could be compared, a series of 10 flights was flown with each of the other two configurations; first with the FLEET configuration and then with the ALOFT/COPPER configuration, especially to check navigation mode functions, delivery of conventional weapons, and MRI weapons. The requirements for each group of flights are given in Tables C-2, C-3, and C-4, respectively.

DEMONSTRATION FLIGHTS

The requirements for the first 10 flights with the ALOFT/FIBER OPTICS configuration were the same as for the baseline flights. A requirement for an eleventh flight with gun and rockets was added as shown in Table C-5.

TABLE C-2. Navigation Mode Functions.

Flight No.	Type	NAV mode	Type alignment
1	North/East	Inertial	Complete ground alignment
2	North/East	Inertial/DIG	Complete ground alignment
3	North/East	DIG	Course leveling complete, airborne alignment
4	North/East	DIG	Course gyrocompassing only, airborne alignment

NOTE: All updates functionally checked on each flight. Wind and doppler checks made.

TABLE C-3. Conventional Weapons Flight Matrix.

Pass No.	Wpn/ASCU code	Rack/sta	Qty/int, ft	Attack mode	Del mode	NAV mode	Ranging	Remarks/loading
Flights 5 and 6								
1	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path, 30-45° dive	Inertial	FLR	
2	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path, 30-45° dive	Inertial	BARO	
3	Mk 76/XHR	MER/2, 7	01/010	Normal	Dive-toss	Inertial	FLR	
4	Mk 76/XHR	MER/2, 7	01/010	Normal	Dive-toss	Inertial	BARO	
5	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path	DIG	FLR	
6	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path	DIG	BARO	
7	Mk 76/XHR	MER/2, 7	01/010	Normal	Dive-toss	DIG	FLR	
8	Mk 76/XHR	MER/2, 7	01/010	Normal	Dive-toss	DIG	BARO	
9	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path	DIG	RAD ALT	
10	Mk 76/XHR	MER/2, 7	01/010	Normal	St. path	Inertial	RAD ALT	
11	Mk 76/XHR		03/010	Manual ripple	Level	Inertial	N.A.	Fully loaded MERs Stations 1, 8, 2 & 7
12	Mk 76/XHR		03/300	Manual ripple	St. path	IMS FAIL	N.A.	

TABLE C-3. (Contd.)

Pass No.	Wpn/ASCU code	Rack/sta	Qty/int, ft	Attack mode	Del mode	NAV mode	Ranging	Remarks/loading
					Flight 7			
1	Mk 76/XHR	MER/2, 7	01/010	Radar	St. path, 45° dive	Inertial	BARO	
2	Mk 76/XHR	MER/2, 7	01/010	Radar	St. path, 45° dive	Inertial	RAD ALT	
3	Mk 76/XHR	MER/2, 7	01/010	Radar	St. path, 45° dive	DIG	BARO	
4	Mk 76/XHR	MER/2, 7	01/010	Radar	Level, 200-500 ft AGL	DIG	BARO	
5	Mk 76/XHR	MER/2, 7	01/010	Radar	Level 200-500 ft AGL	Inertial	BARO	
6	Mk 76/XHR	MER/2, 7	01/010	Radar	Level, 200-500 ft AGL	Inertial	RAD ALT	
7	Mk 76/XHR	MER/2, 7	01/010	Normal offset	St. path, 45° dive	Inertial	BARO	
8	Mk 76/XHR	MER/2, 7	01/010	Radar	St. path, 45° dive	Inertial	RAD ALT	
9	Mk 76/XHR	MER/2, 7	01/010	Nav with update	St. path, 45° dive	DIG	BARO	
10	Mk 76/XHR	MER/2, 7	01/200	Radar offset	St. path, 45° dive	DIG	RAD ALT	

TABLE C-4. MRI Weapons Flight Matrix.

Pass No.	Wpn/ASCU code	Qty/int, ft	Rack/sta	Del mode	Attack mode	g	MRI class	Loading/remarks
Flight 8								
1	Mk 82 LDGP/ XGO	03/010	Parent/ 1, 8, 2	St. path	Normal	<1	III	One Mk 82 on each parent station/ MRI Class I
2	Mk 82 LDGP/ XGO	03/010	Parent/ 7, 3, 6	Dive-toss	Normal	>2	III	
Flight 9								
1	Mk 76/ XHR	03/010	MER/2	Dive-toss	Normal	>2	I, II	Six Mk 76s on MER sta 2 Six Mk 106s on MER sta 7
2	Mk 76/ XHR	03/010	MER/2	St. path	Normal	<1	I, II	
3	Mk 106/ XHP	03/010	MER/7	St. path	Normal	<1	I, II	
4	Mk 106/ XHP	03/010	MER/7	Level	Manual ripple	1	I, II	
Flight 10								
1	Mk 83 Con/ XGS	03/010	Parent/1, MER/7	St. path	Manual ripple	<1	II Safety feature	One Mk 83 Con on Parent 1 and 8 Two Mk 83s Con on MERs 2 and 7
2	Mk 83 Con/ XGS	03/010	Parent/8, MER/7	Dive-toss	Manual ripple	>2	II Safety feature	

Appendix D
ALOFT RELIABILITY AND MAINTAINABILITY RESULTS

RELIABILITY

For purposes of comparison of the ALOFT computer and peripheral avionics WRA reliability with that of equivalent FLEET equipment, monthly maintenance data tapes were obtained from Naval Air Station, Lemoore, CA. Attack Squadrons 146 and 147 were selected based on an evaluation of squadron deployment schedules, operational mission profiles, and mission system maintenance philosophy. These squadrons' operations were similar to those used for the ALOFT project at NWC in that flights were begun with an all-up avionics system, flight profiles included both navigation and weapon delivery flights, and maintenance had a high level of documentation accuracy. These fleet data were inputted to a NAVAIRTESTCEN computerized R&M data analysis program which provided statistically valid R&M parameters for a comparative baseline.

ALOFT-Peculiar WRA Reliability

There were no failures of ALOFT-peculiar WRAs during the 72-flight-hour evaluation. The small number of flight hours accumulated on the ALOFT aircraft reduced the confidence in the reliability analysis. Ideally, several thousand flight hours are required to achieve confidence in the data. Since no failures occurred to the ALOFT-peculiar WRAs, the mean flight hours between failure (MFHBF) is greater than 72.1. Using tactical computer operating hours, the mean time between failure (MTBF) is greater than 135.

Fiber Optic Connector Failures

There were three failures of the fiber optic cable in the ALOFT aircraft. Two failures were at the J2 connector of the left bay adapter. The first occurred during system installation when the cable was pulled at a right angle to the connector which broke the cable at the connector. The cable was reterminated at the aircraft by the IBM representative. This was his first termination attempt. Although the connector was functional following termination, it contained excessive broken fibers and appeared to be poorly terminated. The lack of additional spare connector hardware at NWC prevented a second repair attempt and it was decided to continue into the flight test phase. The same connector failed after being subjected to excessive handling by visitors inspecting the installation following a weapons delivery demonstration

at NWC. The cable was satisfactorily reterminated and functional for the remainder of the flight test phase. Both failures were caused by improper or excessive handling and were not relevant to the reliability of the ALOFT system. One additional failure occurred at J4 of the FLR adapter. Although still functional, visual inspection revealed the outer jacket was improperly prepared prior to bonding and had become loose from the connector shell. It was reterminated and the flight test continued. This failure was also classified as not relevant.

ALOFT Peripheral System Reliability

The ALOFT system, in providing the direct interface between the A-7 NWDS tactical computer and its integrated peripheral avionics, has a direct effect on the observed reliability of the peripheral systems. Table D-1 summarizes the reliability of eight peripheral avionics systems interfaced by ALOFT and lists FLEET reliability for those same systems.

The observed mean flight hours (FHs) between maintenance action (MFHBMA) and MFHBF using both relevant and nonrelevant failures is 10.3 (seven MAs) and 24.0 (three failures) which compares to the FLEET parameters demonstrated reliability of 7.4 and 21.6. The observed MFHBMA and MFHBF using relevant failures was 18 and 24. Although the three failures of the fiber optic cable are classified as nonrelevant from a reliability design standpoint, it is felt that the inclusion of these failures is more realistic to what would be experienced in the field. Therefore, using upper and lower factors for determining 90% confidence levels with seven observed failures (Table D-2), the true MFHBMA lies between 6.1 and 21.9, and the true MFHBF lies between 14.2 and 51.1.

Maintainability Maintenance Concept

The maintenance concept recommended for organizational (0) level and intermediate (1) level repair of optically coupled WRA is the same as for copper/coaxial counterparts in that replacement of the WRA is at the 0 level and repair of the WRA is at the 1 or depot level. The maintenance concept recommended for repair of fiber optic cable is replacement at the 0 level if simple retermination cannot effect repair. Where replacement is not practical, information must be provided which delineates the allowable number of splices each cable is permitted prior to mandatory replacement.

TABLE D-1. Peripheral Avionics Systems Reliability.

WUC	Nomenclature	FLEET[a]		ALOFT[b]		ALOFT failures	
		MFHBMA	MFHBF	MFHBMA	MFHBF	Non-relevant	Relevant
71X1R	ID 1329/A Attitude Direction Industry	65.0	171.2	>72.1	>72.1	0	0
73A1600	SG811/APQ116 Sweep Generator	112.4	235.1	72.1[a]	>72.1	1	0
73A20	AN/ASN-91(V) Tactical Computer Set	31.1	88.9	36[b]	36	2	2
73A30	AN/APN-190 Navigation Set	25.5	60.7	>72.1	>72.1	0	0
73A40	AN/AVQ-7(V) Head-Up Display Set	21.7	55.8	24[c]	>72.1	3	0
73A50	AN/ASN-90(V) Inertial Measurement Set	12.9	35.1	>72.1	72.1	1	1
735A0	AN/ASN-99(V) Projected Map Display	42.1	88.7	>72.1	>72.1	0	0
7411B	C8185/AWE Armament Station Control	172.4	654.6	72.1	>72.1	0	0
Total		7.4	21.6	10.3	24	7	3
Total (less non-relevant ALOFT MA)[c]				18[d]	24		

[a] FLEET data base 51,711 flight hours.
[b] ALOFT data base 72.1 flight hours.
[c] ALOFT cable repair (nonrelevant).
[d] Both failures non-ALOFT components.

TABLE D-2. Confidence Levels.

	MFHBMA	MFHBF
FLEET system reliability (51,711 FH)	7.4	21.6
ALOFT system reliability (72.1 FH)	10.3	24.0
Lower 90% confidence	6.1	14.2
Upper 90% confidence	21.9	51.1

Troubleshooting ALOFT Peripheral Avionics

The maintainability of the ALOFT fiber optic system was very good. The adapter units were located for minimal impact on avionic system maintenance with exception of the FLR adapter which required removal to facilitate radar sweep generator maintenance. Incorporation of the ALOFT system enhanced peripheral avionics maintenance in that fault isolation to the WRA is easier using multiplexed data transfer. Where a normal system has numerous wires carrying data through many cables and connectors, the multiplexed system utilizes one cable but carries data from numerous systems concurrently. Therefore, if the other systems continue to operate correctly, the multiplex cable cannot be suspect and the failure most likely is with the WRA or, as is possible in this system, within the interface optical adapter unit. In the event an adapter unit or single optical cable fails, data from those associated systems are absent from their displays and easily recognizable to the operator.

Troubleshooting Fiber Optic Cables

Troubleshooting of optical cables requires a light source and access to both ends. Major breaks are visually recognized by the absence of light at one end of the cable when a light source (from a flashlight, overhead light, or hangar door opening) is applied to the other end. Low-light-level transmission caused by broken fibers can be determined using a pencil type magnifier of approximately 40 power with a good light source. The maximum allowable broken fibers in a single cable depends upon individual circuit components, length of cable, and number of terminations.

Fiber Optic Cable Repair

Repair of a damaged fiber optic cable is made by using connector hardware. Since optical loss is approximately 3 dB per junction, it is necessary to replace the cable if losses cannot be tolerated. Where higher losses are acceptable, the cable is terminated with connector hardware and the damaged section replaced. In most cases, the damage is at or near the connector which may be reterminated using new connector hardware. Terminations are relatively easy to perform using the following material and equipment: sandpaper, wire strippers, alcohol, epoxy, heat gun, and coarse metal and fine phenolic lapidary tools. The ease of repair of fiber optic cables is an enhancing characteristic which should be incorporated in future designs of high-data-rate, digital-multiplex systems.

Appendix E
OPTICAL SYSTEM SIGNAL LIST

TABLE E-1. A-7 Optical System Signal List.

A. ASCU Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
ARMAMENT STATION CONTROL UNIT	WEAPON TYPE 80	5V DISCRETE	TO	W.T. 80 J6-1 0V=1 RETURN J6-2	LLR
	WEAPON TYPE 40	5V DISCRETE	TO	W.T. 40 J6-3 0V=1 RETURN J6-4	LLR
	WEAPON TYPE 20	5V DISCRETE	TO	W.T. 20 J6-5 0V=1 RETURN J6-6	LLR
	WEAPON TYPE 10	5V DISCRETE	TO	W.T. 10 J6-7 0V=1 RETURN J6-8	LLR
	WEAPON TYPE 8	5V DISCRETE	TO	W.T. 8 J6-9 0V=1 RETURN J6-10	LLR
	WEAPON TYPE 4	5V DISCRETE	TO	W.T. 4 J6-11 0V=1 RETURN J6-12	LLR
	WEAPON TYPE 2	5V DISCRETE	TO	W.T. 2 J6-13 0V=1 RETURN J6-14	LLR
	WEAPON TYPE 1	5V DISCRETE	TO	W.T. 1 J6-20 0V=1 RETURN J6-21	LLR
	STATION 1 READY	5V DISCRETE	TO	S1R J6-22 0V=1 RETURN J6-23	LLR
	STATION 2 READY	5V DISCRETE	TO	S2R J6-24 0V=1 RETURN J6-25	LLR
	STATION 3 READY	5V DISCRETE	TO	S3R J6-26 0V=1 RETURN J6-27	LLR
	STATION 6 READY	5V DISCRETE	TO	S6R J6-28 0V=1 RETURN J6-29	LLR
	STATION 7 READY	5V DISCRETE	TO	S7R J6-30 0V=1 RETURN J6-31	LLR
	STATION 8 READY	5V DISCRETE	TO	S8R J6-32 0V=1 RETURN J6-33	LLR
	GUNS SELECTED	5V DISCRETE	TO	G.S. J6-42 0V=1 RETURN J6-43	LLR
	MULTIPLE LOADING	5V DISCRETE	TO	M.L. J6-44 0V=1 RETURN J6-45	LLR
	RELEASE ENABLE	5V DISCRETE	TO	R.E. J6-46 5V=1 RETURN J6-47	DER
	BOMB RELEASE	5V DISCRETE	FROM	B.R. J6-48 5V=1 RETURN J6-49	LLD
	FIRE READY	5V DISCRETE	FROM	F.R. J6-50 5V=1 RETURN J6-51	LLD

TABLE E-1. (Contd.)

B. Left Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
INERTIAL MEASUREMENT SET	GYRO TORQUING X	5V PULSE TRAIN	FROM	GYROX J8-10 5V=1 Return J8-11	LLD
	GYRO TORQUING Y	5V PULSE TRAIN	FROM	GYROY J8-12 5V=1 RETURN J8-13	LLD
	GYRO TORQUING Z	5V PULSE TRAIN	FROM	GYROZ J8-29 5V=1 RETURN J8-30	LLD
	SAMPLE CLOCK	5V 200 pps	FROM	SAMP. C. J8-31 0V=1 RETURN J8-32	LLD
	SCALE FACTOR CHANGE	5V DISCRETE	FROM	S.F.C. J8-3 5V=1 RETURN J8-4	LLD
	AZIMUTH SLEW	5V DISCRETE	FROM	A.Z.S. J8-20 5V=1 RETURN J8-21	LLD
	AZIMUTH SLEW SENSE	5V DISCRETE	FROM	A.Z.S.S. J8-22 5V=1 RETURN J8-23	LLD
	LATITUDE 70°	5V DISCRETE	FROM	LAT 70 J8-24 5V=1 RETURN J8-25	LLD
	COMPUTER FAILED	5V DISCRETE	FROM	C.F. J8-40 5V=1 RETURN J8-41	LLD
	COMPUTER CONTROL MODE	5V DISCRETE	FROM	C.C.M. J8-42 5V=1 RETURN J8-43	LLD
	AUTO CALIBRATE	5V DISCRETE	FROM	AUTO. C. J8-44 0V=1 RETURN J8-45	LLD
	X SLEW	5V DISCRETE	FROM	X.S. J8-61 5V=1 RETURN J8-62	LLD
	X SLEW SENSE	5V DISCRETE	FROM	X.S.S. J8-63 5V=1 RETURN J8-64	LLD
	Y SLEW	5V DISCRETE	FROM	Y.S. J8-65 5V=1 RETURN J8-66	LLD
	Y SLEW SENSE	5V DISCRETE	FROM	Y.S.S. J8-81 5V=1 RETURN J8-82	LLD
	EAST VELOCITY POSITIVE	5V PULSE TRAIN	TO	E.V.P. J8-51 5V=1 RETURN J8-52	LLR
	EAST VELOCITY NEGATIVE	5V PULSE TRAIN	TO	E.V.N. J8-53 5V=1 RETURN J8-74	LLR
	NORTH VELOCITY POSITIVE	5V PULSE TRAIN	TO	N.V.P. J8-70 5V=1 RETURN J8-71	LLR

TABLE E-1. (Contd.)

B. Left Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
INERTIAL MEASUREMENT SET	NORTH VELOCITY NEGATIVE	5V PULSE TRAIN	TO	N.V.N. J8-72 5V=1 RETURN J8-73	LLR
	VERTICAL VELOCITY POSITIVE	5V PULSE TRAIN	TO	V.V.P. J8-92 5V=1 RETURN J8-93	LLR
	VERTICAL VELOCITY NEGATIVE	5V PULSE TRAIN	TO	V.V.N. J8-94 5V=1 RETURN J8-95	LLR
	IMS READY	5V DISCRETE	TO	I.M.S.R. J8-85 5V=1 RETURN J8-86	LLR
	IMS FAIL	5V DISCRETE	TO	I.M.S.F. J8-83 5V=1 RETURN J8-84	LLR
	AUTO CALIBRATION MODE	SWITCH CLOSURE	TO	A.C.M. J8-90 SHRT=OPN RETURN J8-91 SHRT=1	SER
MASTER SELECTION SWITCH	NORMAL MODE	SWITCH CLOSURE	TO	N.M. J9-20 SHRT=OPN RETURN J9-21 SHRT=1	SER
	OFFSET MODE	SWITCH CLOSURE	TO	O.M. J9-22 SHRT=1 RETURN J9-23	SER
	RADAR/BOMB	SWITCH CLOSURE	TO	R/B J9-24 SHRT=1 RETURN J9-25	SER
	NAVIGATION/BOMB	SWITCH CLOSURE	TO	N/B J9-33 SHRT=1 RETURN J9-34	SER
HUD ELECTRONICS	DATA OUT	50 KHZ DIGITAL	FROM	TRUE J8-16 0V=1 COMP. J8-17 5V=1	LLD (DIFF)
	ADDRESS OUT	50 KHZ DIGITAL	FROM	TRUE J8-36 5V=1 COMP. J8-37	LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	TRUE J8-57 5V=1 COMP. J8-58	LLD (DIFF)
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	TRUE J8-78 5V=1 COMP. J8-79	LLD (DIFF)
	DATA COMMON	GND	TO	J8-96	

TABLE E-1. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
NAVIGATION WEAPON DELIVERY PANEL	DATA IN	1 MHZ DIGITAL	TO	TRUE J7-101 0V=1 COMP. J7-100 5V=1	DER
	SELF TEST	5V DISCRETE	TO	S.T. J7-89 0V=1 RETURN J7-90	SER
	NAV/WD INTERRUPT	5V DISCRETE	TO	N./W. I. J7-91 0V=1 RETURN J7-92	LLR
	DATA OUT	1 MHZ DIGITAL	FROM	TRUE J7-60 0V=1 COMP. J7-59	LLD (DIFF)
	ADDRESS 1	5V DISCRETE	FROM	ADD. 1 J7-14 0V=1 RETURN J7-15	LLD
	ADDRESS 2	5V DISCRETE	FROM	ADD. 2 J7-34 0V=1 RETURN J7-35	LLD
	ADDRESS 3	5V DISCRETE	FROM	ADD. 3 J7-55 0V=1 RETURN J7-56	LLD
	ADDRESS 4	5V DISCRETE	FROM	ADD. 4 J7-74 0V=1 RETURN J7-75	LLD
	READ	5V DISCRETE	FROM	READ J7-76 0V=1 RETURN J7-77	LLD
	WRITE	5V DISCRETE	FROM	WRITE J7-94 0V=1 RETURN J7-95	LLD
	SHIFT CLOCK	1 MHZ DIGITAL	FROM	TRUE J7-19 0V=1 COMP. J7-18	LLD (DIFF)
	TIMING CLOCK	1 MHZ DIGITAL	FROM	TRUE J7-39 0V=1 COMP. J7-38	LLD (DIFF)
	RESET DELAY	5V DISCRETE	FROM	R.S. J7-96 0V=1 RETURN J7-97	LLD
THROTTLE	BOMB FALL LINE 1	5V PULSE	TO	B.F.L. 1 J7-42 0V=1 RETURN J7-43	LLR
	BOMB FALL LINE 2	5V PULSE	TO	B.F.L. 2 J7-53 0V=1 RETURN J7-54	LLR
ARMAMENT SELECT PANEL	BOMB HIGH DRAG	28VDC DISCRETE	TO	J9-45 28V=1	HVR
IMS CONTROLLER	NORMAL MODE	SWITCH CLOSURE	TO	N.M. J8-47 SHRT=OPN RETURN J8-48 SHRT=1	SER
	INERTIAL MODE	SWITCH CLOSURE	TO	I.M. J8-49 SHRT=1 RETURN J8-50	SER
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	M.S. J8-88 SHRT=1 RETURN J8-89	SER
	GRID MODE	SWITCH CLOSURE	TO	G.M. J8-68 SHRT=1 RETURN J8-69	SER

TABLE E-1. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
NAVIGATION WEAPON DELIVERY PANEL	DATA IN	1 MHZ DIGITAL	TO	TRUE J7-101 0V=1 COMP. J7-100 5V=1	DER
	SELF TEST	5V DISCRETE	TO	S.T. J7-89 0V=1 RETURN J7-90	SER
	NAV/WD INTERRUPT	5V DISCRETE	TO	N./W. I. J7-91 0V=1 RETURN J7-92	LLR
	DATA OUT	1 MHZ DIGITAL	FROM	TRUE J7-60 0V=1 COMP. J7-59	LLD (DIFF)
	ADDRESS 1	5V DISCRETE	FROM	ADD. 1 J7-14 0V=1 RETURN J7-15	LLD
	ADDRESS 2	5V DISCRETE	FROM	ADD. 2 J7-34 0V=1 RETURN J7-35	LLD
	ADDRESS 3	5V DISCRETE	FROM	ADD. 3 J7-55 0V=1 RETURN J7-56	LLD
	ADDRESS 4	5V DISCRETE	FROM	ADD. 4 J7-74 0V=1 RETURN J7-75	LLD
	READ	5V DISCRETE	FROM	READ J7-76 0V=1 RETURN J7-77	LLD
	WRITE	5V DISCRETE	FROM	WRITE J7-94 0V=1 RETURN J7-95	LLD
	SHIFT CLOCK	1 MHZ DIGITAL	FROM	TRUE J7-19 0V=1 COMP. J7-18	LLD (DIFF)
	TIMING CLOCK	1 MHZ DIGITAL	FROM	TRUE J7-39 0V=1 COMP. J7-38	LLD (DIFF)
	RESET DELAY	5V DISCRETE	FROM	R.S. J7-96 0V=1 RETURN J7-97	LLD
THROTTLE	BOMB FALL LINE 1	5V PULSE	TO	B.F.L. 1 J7-42 0V=1 RETURN J7-43	LLR
	BOMB FALL LINE 2	5V PULSE	TO	B.F.L. 2 J7-53 0V=1 RETURN J7-54	LLR
ARMAMENT SELECT PANEL	BOMB HIGH DRAG	28VDC DISCRETE	TO	J9-45 28V=1	HVR
IMS CONTROLLER	NORMAL MODE	SWITCH CLOSURE	TO	N.M. J8-47 SHRT=OPN RETURN J8-48 SHRT=1	SER
	INERTIAL MODE	SWITCH CLOSURE	TO	I.M. J8-49 SHRT=1 RETURN J8-50	SER
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	M.S. J8-88 SHRT=1 RETURN J8-89	SER
	GRID MODE	SWITCH CLOSURE	TO	G.M. J8-68 SHRT=1 RETURN J8-69	SER

TABLE E-1. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
	GROUND ALIGN MODE	SWITCH CLOSURE	TO	G.A.M. J8-27 SHRT=OPN RETURN J8-28 SHRT=1	SER
ARMAMENT RELEASE PANEL	WEAPON QUAN. 80	SWITCH CLOSURE	TO	W.Q. 80 J7-7 SHRT=OPN RETURN J7-8 SHRT=1	SER
	WEAPON QUAN. 40	SWITCH CLOSURE	TO	W.Q. 40 J7-9 SHRT=1 RETURN J7-10	SER
	WEAPON QUAN. 20	SWITCH CLOSURE	TO	W.Q. 20 J7-11 SHRT=1 RETURN J7-12	SER
	WEAPON QUAN. 10	SWITCH CLOSURE	TO	W.Q. 10 J7-24 SHRT=1 RETURN J7-25	SER
	WEAPON QUAN. 8	SWITCH CLOSURE	TO	W.Q. 8 J7-26 SHRT=1 RETURN J7-27	SER
	WEAPON QUAN. 4	SWITCH CLOSURE	TO	W.Q. 4 J7-28 SHRT=1 RETURN J7-29	SER
	WEAPON QUAN. 2	SWITCH CLOSURE	TO	W.Q. 2 J7-30 SHRT=1 RETURN J7-31	SER
	WEAPON QUAN. 1	SWITCH CLOSURE	TO	W.Q. 1 J7-44 SHRT=1 RETURN J7-45	SER
	WEAPON SPACING 800	SWITCH CLOSURE	TO	W.S. 800 J7-46 SHRT=1 RETURN J7-47	SER
	WEAPON SPACING 400	SWITCH CLOSURE	TO	W.S. 400 J7-48 SHRT=1 RETURN J7-49	SER
	WEAPON SPACING 200	SWITCH CLOSURE	TO	W.S. 200 J7-50 SHRT=1 RETURN J7-51	SER
	WEAPON SPACING 100	SWITCH CLOSURE	TO	W.S. 100 J7-32 SHRT=1 RETURN J7-52	SER
	WEAPON SPACING 80	SWITCH CLOSURE	TO	W.S. 80 J7-65 SHRT=1 RETURN J7-66	SER
	WEAPON SPACING 40	SWITCH CLOSURE	TO	W.S. 40 J7-67 SHRT=OPN RETURN J7-68 SHRT=1	SER
	WEAPON SPACING 20	SWITCH CLOSURE	TO	W.S. 20 J7-69 SHRT=OPN RETURN J7-70 SHRT=1	SER
	WEAPON SPACING 10	SWITCH CLOSURE	TO	W.S. 10 J7-71 SHRT=OPN RETURN J7-72 SHRT=1	SER
	PAIRS SELECTED	SWITCH CLOSURE	TO	P.S. J7-85 SHRT=OPN RETURN J7-86 SHRT=1	SER
	PAIRS INT. COMMON WEAPONS QUAN. COMMON	GND GND	FROM	J7-47 J7-8	

TABLE E-1. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
ATTITUDE DIRECTION INDICATOR	COMPUTER RELIABLE	5V DISCRETE	FROM	COMP. REL. J7-5 5V=1 RETURN J7-6	LLD
	STEERING ERROR	±2.5V ANALOG	FROM	HI J4-81 LO J4-82	
PILOT STICK GRIP	TGT. DESIG. NOT	28 VDC DISCRETE	TO	J7-87 0V=1	HVR
BULLPUP CONTROL STICK	AZIMUTH RATE	±4VDC ANALOG	TO	J4-2	10 MEG
	+4V REF	ANALOG	TO	J4-1	
	−4V REF	ANALOG	TO	J4-3	
	ELEVATION RATE	±4VDC ANALOG	TO	J4-5	10 MEG
	BPC POT CNTR TAP	GND	TO	J4-10	
FLR CONTROL SET	CURSOR ENABLE	28VDC DISCRETE	FROM	J9-41 28V=1	HVD
	ANTENNA SLAVE	28 VDC DISCRETE	FROM	J9-43 28V=1	HVD
ADVISORY CAUTION PNL	COMPUTER FAIL	28V DISCRETE	FROM	J7-20	HVD
	IMU NOT ALIGNED	28V DISCRETE	FROM	J7-61	HVD

TABLE E-1. (Contd.)

D. FLR Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
FLR SWEEP GENERATOR	CHANNEL CLOCK	50 KHZ DIGITAL	FROM	TRUE J9-4 0V=1 COMP J9-5 5V=1	LLD (DIFF)
	DATA OUT	50 KHZ DIGITAL	FROM	TRUE J9-6 0V=1 COMP J9-7 5V=1	LLD (DIFF)
	ADDRESS OUT	50 KHZ DIGITAL	FROM	TRUE J9-16 0V=1 COMP J9-17 5V=1	LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	TRUE J9-27 0V=1 COMP J9-28 5V=1	LLD (DIFF)
	COMPUTER RELIABLE	28VDC DISCRETE	FROM	J9-31 28V=1	HVD
	DATA IN	50 KHZ DIGITAL	TO	TRUE J9-8 0V=1 COMP J9-9 5V=1	DER
	ADDRESS IN	50 KHZ DIGITAL	TO	TRUE J9-18 0V=1 COMP J9-19 5V=1	DER
	READY IN	50 KHZ DIGITAL	TO	TRUE J9-29 0V=1 COMP J9-30 5V=1	DER
	AGR TEST	28 VDC DISCRETE	FROM	1J9-12 28V=1	HVD
	DATA COMMON	GND	TO	J9-38	

TABLE E-1. (Contd.)

E. Right Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
DOPPLER RADAR ELECTRONICS	DATA IN	50 KHZ DIGITAL	TO	TRUE J8-18 COMP J8-19	DER
	ADDRESS IN	50 KHZ DIGITAL	TO	TRUE J8-38 COMP J8-39	DER
	READY IN	50 KHZ DIGITAL	TO	TRUE J8-59 COMP J8-60	DER
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	TRUE J8-100 COMP J8-101	LLD (DIFF)
PROJECTED MAP ELECTRONICS UNIT	DATA OUT	50 KHZ DIGITAL	FROM	TRUE J8-54 0V=1 COMP J8-75 5V=1	LLD (DIFF)
	ADDRESS OUT	50 KHZ DIGITAL	FROM	TRUE J8-46 5V=1 COMP J8-67	LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	TRUE J8-07 5V=1 COMP J8-26	LLD (DIFF)
	CLOCK OUT	50 KHZ DIGITAL	FROM	TRUE J8-14 5V=1 COMP J8-33	LLD (DIFF)
	DATA COMMON	GND	FROM	J8-96	

TABLE E-2. A-7 Multiplexed Optical Signal List.

A. ASCU Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
ARMAMENT STATION CONTROL UNIT	WEAPON TYPE 80	5V DISCRETE	TO	W.T. 80 J-308 P2-125 RETURN	J4-45 J4-46	LLR
	WEAPON TYPE 40	5V DISCRETE	TO	W.T. 40 J-308 P2-124 RETURN	J4-43 J4-44	LLR
	WEAPON TYPE 20	5V DISCRETE	TO	W.T. 20 J-308 P2-123 RETURN	J4-34 J4-35	LLR
	WEAPON TYPE 10	5V DISCRETE	TO	W. T. 10 J-308 P2-122 RETURN	J4-36 J4-37	LLR
	WEAPON TYPE 8	5V DISCRETE	TO	W.T. 8 J-308 P2-115 RETURN	J4-32 J4-33	LLR
	WEAPON TYPE 4	5V DISCRETE	TO	W.T. 4 J-308 P2-114 RETURN	J4-30 J4-31	LLR
	WEAPON TYPE 2	5V DISCRETE	TO	W.T. 2 J-308 P2-113 RETURN	J4-26 J4-27	LLR
	WEAPON TYPE 1	5V DISCRETE	TO	W.T. 1 J-308 P2-112 RETURN	J4-28 J4-29	LLR
	STATION 1 READY	5V DISCRETE	TO	S.1 R. J-308 P2-134 RETURN	J4-24 J4-25	LLR
	STATION 2 READY	5V DISCRETE	TO	S.2 R. J-308 P2-135 RETURN	J4-22 J4-23	LLR
	STATION 3 READY	5V DISCRETE	TO	S.3 R. J-308 P2-136 RETURN	J4-18 J4-19	LLR
	STATION 6 READY	5V DISCRETE	TO	S.6 R. J-308 P2-137 RETURN	J4-20 J4-21	LLR
	STATION 7 READY	5V DISCRETE	TO	S.7 R. J-308 P2-138	J4-16 J4-17	LLR
	STATION 8 READY	5V DISCRETE	TO	S.8 R. J-308 P2-139 RETURN	J4-14 J4-15	LLR
	GUNS SELECTED	5V DISCRETE	TO	G.S. J-308 P2-126 RETURN	J4-5 J4-6	LLR
	MULTIPLE LOADING	5V DISCRETE	TO	M.L. J-308 P2-116 RETURN	J4-12 J4-13	LLR
	RELEASE ENABLE	5V DISCRETE	TO	R.E. J-308 P2-141 RETURN	J4-3 J4-4	DER
	BOMB RELEASE	5V DISCRETE	FROM	B.R. J-308 P2-143 RETURN	J4-49 J4-50	LLD
	FIRE READY	5V DISCRETE	FROM	F.R. J-308 P2-142 RETURN	J4-47 J4-48	LLD
	CHASSIS GND				J4-51	

TABLE E-2. (Contd.)

B. Left Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
HUD	DATA COMMON	GND	TO	P3050 2J1-47	J4-65	LLD
ELECTRONICS	DATA OUT	50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-17	J4-31	(DIFF)
		50 KHZ DIGITAL		P3050 COMP 2J1-16	J4-32	
	ADDRESS OUT	50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-32	J4-29	LLD (DIFF)
				P3050 COMP 2J1-30		LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-5	J4-15	LLD (DIFF)
				P3050 COMP 2J1-4	J4-16	LLD (DIFF)
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-12	J4-70	LLD (DIFF)
				P3050 COMP 2J1-26	J4-71	LLD (DIFF)
INERTIAL	GYRO TORQUING X	5V PULSE TRAIN	FROM	P3096 G.T.X. 1J1-12	J4-45	LLD (DIFF)
MEASUREMENT				P3096 RETURN 1J1-31	J4-46	
SET	GYRO TORQUING Y	5V PULSE TRAIN	FROM	P3096 G.T.Y. 1J1-49	J4-63	LLD
				P3096 RETURN 1J1-52	J4-64	(DIFF)
	GYRO TORQUING Z	5V PULSE TRAIN	FROM	P3096 G.T.Z. 1J1-28	J4-61	LLD
				P3096 RETURN 1J1-53	J4-62	(DIFF)
	SAMPLE CLOCK	5V 200 PPS	FROM	P3096 SC 1J1-4	J4-41	LLD
				P3096 RETURN 1J1-15	J4-42	(DIFF)
	SCALE FACTOR CHANGE	5V DISCRETE	FROM	P3045 S.F.C. 2J5-16	J4-17	LLD
				P3045 RETURN 2J5-36	J4-18	(DIFF)
	AZIMUTH SLEW	5V DISCRETE	FROM	P3045 A.S. 2J5-17	J4-72	LLD
				P3045 RETURN 2J5-36	J4-73	(DIFF)
	AZIMUTH SLEW SENSE	5V DISCRETE	FROM	P3045 A.S.S. 2J5-18	J4-74	LLD
				P3045 RETURN 2J5-37	J4-75	(DIFF)
	LATITUDE 70°	5V DISCRETE	FROM	P3045 L. 70 2J5-20	J4-25	LLD
				P3045 RETURN 2J5-21	J4-26	(DIFF)
	COMPUTER FAILED	5V DISCRETE	FROM	P3045 C.F. 2J5-19	J4-21	LLD
				P3045 RETURN 2J5-21	J4-22	(DIFF)
	COMPUTER CONTROL	5V DISCRETE	FROM	P3045 C.C.M. 2J5-15	J4-78	LLD (DIFF)
	MODE			P3045 RETURN 2J5-36	J4-79	LLD (DIFF)

TABLE E-2. (Contd.)

B. Left Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
INERTIAL	AUTO CALIBRATE	5V DISCRETE	FROM	P3045 A.C. 2J5-26	J4-76	LLD
MEASUREMENT				P3045 RETURN 2J5-37	J4-77	
SET	X SLEW	5V DISCRETE	FROM	P3096 X.S. 1J1-27	J4-7	LLD
				P3096 RETURN 1J1-30	J4-8	
	X SLEW SENSE	5V DISCRETE	FROM	P3096 X.S.S. 1J1-1	J4-3	LLD
				P3096 RETURN 1J1-5	J4-4	
	Y SLEW	5V DISCRETE	FROM	P3096 Y.S. 1J1-47	J4-33	LLD
				P3096 RETURN 1J1-51	J4-34	
	Y SLEW SENSE	5V DISCRETE	FROM	P3096 Y.S.S. 1J1-45	J4-37	LLD
				P3096 RETURN 1J1-14	J4-38	
	EAST VELOCITY	5V PULSE TRAIN	TO	P3096 E.V.P. 1J1-54	J4-47	LLR
	POSITIVE	5V PULSE TRAIN		P3096 RETURN 1J1-16	J4-48	
	EAST VELOCITY	5V PULSE TRAIN	TO	P3096 E.V.N. 1J1-6	J4-5	LLR
	NEGATIVE	5V PULSE TRAIN		P3096 RETURN 1J1-32	J4-6	LLR
	NORTH VELOCITY	5V PULSE TRAIN	TO	P3096 N.V.P. 1J1-56	J4-43	LLR
	POSITIVE			P3096 RETURN 1J1-17	J4-44	
	NORTH VELOCITY	5V PULSE TRAIN	TO	P3096 N.V.N. 1J1-34	J4-35	LLR
	NEGATIVE			P3096 RETURN 1J1-18	J4-36	
	VERTICAL VELOCITY	5V PULSE TRAIN	TO	P3096 V.V.P. 1J1-36	J4-39	LLR
	POSITIVE			P3096 RETURN 1J1-8	J4-40	
	VERTICAL VELOCITY	5V PULSE TRAIN	TO	P3096 V.V.N. 1J1-59	J4-1	LLR
	NEGATIVE			P3096 RETURN 1J1-19	J4-2	LLR
	IMS READY	5V DISCRETE	TO	P3045 I.R. 2J5-22	J4-53	LLR
				P3045 RETURN 2J5-28	J4-54	
	IMS FAIL	5V DISCRETE	TO	P3045 I.F. 2J5-23	J4-49	LLR
				P3045 RETURN 2J5-28	J4-50	
	AUTO CALIBRATION	SWITCH CLOSURE	TO	P3045 A.C.M. 2J5-13	J4-57	SER
	MODE			P3045 RETURN 2J5-14	J4-58	
MASTER	NORMAL MODE	SWITCH CLOSURE	TO	P3064 N.M. J1-40	J4-51	SER
FUNCTION				P3064 RETURN J1-38	J4-52	
SWITCH	OFFSET MODE	SWITCH CLOSURE	TO	P3065 O.M. J1-5	J4-27	SER
				P3065 RETURN J1-6	J4-28	
	RADAR/BOMB	SWITCH CLOSURE	TO	P3064 R.B. J1-15	J4-23	SER
				P3064 RETURN J1-16	J4024	
	NAVIGATION/BOMB	SWITCH CLOSURE	TO	P3064 N.B. J1-25	J4-19	SER
				P3064 RETURN J1-43	J4-20	
	CHASSIS GND				J4-68	
	CHASSIS GND				J4-67	

TABLE E-2. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
NAVIGATION	DATA IN	1 MHZ DIGITAL	TO	P2042 TRUE 2J3-24	J4-65	DER
WEAPON				P2042 COMP 2J3-25	J4-66	
DELIVERY	SELF TEST	5V DISCRETE	TO	P2042 S.T. 2J3-29	J4-23	LLR
PANEL				P2042 SHIELD 2J3-30	J4-24	LLR
	NAVI WD	5V. DISCRETE	TO	P2042 N.W.I. 2J3-27	J4-27	LLR
	INTERRUPT			P2042 RETURN 2J3-28	J4-28	LLR
	DATA OUT	1 MHZ DIGITAL	FROM	P2042 TRUE 2J3-1	J4-31	LLD
				P2042 COMP 2J3-2	J4-32	(DIFF)
	ADDRESS 1	5V DISCRETE	FROM	P2042 ADD 1 2J3-14	J4-49	LLD
				P2042 RETURN 2J3-15	J4-50	
	ADDRESS 2	5V DISCRETE	FROM	P2042 ADD 2 2J3-16	J4-51	
				P2042 RETURN 2J3-17	J4-52	LLD
	ADDRESS 3	5V DISCRETE	FROM	P2042 ADD 3 2J3-18	J4-53	LLD
				P2042 RETURN 2J3-19	J4-54	LLD
	ADDRESS 4	5V DISCRETE	FROM	P2042 ADD 4 2J3-20	J4-55	LLD
				P2042 RETURN 2J3-21	J4-56	LLD
	READ	5V DISCRETE	FROM	P2042 READ 2J3-12	J4-57	LLD
				P2042 RETURN 2J3-13	J4-58	LLD
	WRITE	5V DISCRETE	FROM	P2042 WRITE 2J3-10	J4-59	LLD
				P2042 RETURN 2J3-11	J4-60	LLD
	SHIFT CLOCK	1 MHZ DIGITAL	FROM	P2042 TRUE 2J3-5	J4-15	LLD
				P2042 COMP 2J3-4	J4-16	(DIFF)
	TIMING CLOCK	1 MHZ DIGITAL	FROM	P2042 TRUE 2J3-8	J4-67	
				P2042 COMP 2J3-7	J4-68	LLD (DIFF)
	RESET DELAY	5V DISCRETE	FROM	P2042 R.D. 2J3-22	J4-9	LLD
				P2042 RETURN 2J3-23	J4-10	
THROTTLE	BOMB FALL	5V PULSE	TO	P255 BFL1 JJ1-32	J4-1	LLR
	LINE 1			P255 RETURN JJ1-33	J4-2	
	BOMB FALL	5V PULSE	TO	P255 BFL2 JJ1-34	J4-5	LLR
	LINE 2			P255 RETURN JJ1-35	J4-6	
ARMAMENT	BOMB HIGH DRAG	28 VDC DISCRETE	TO	J264 P1-48	J4-74	HVR
IMS	NORMAL MODE	SWITCH CLOSURE	TO	P2045 N.M. 3J1-7	J4-79	SER
CONTROLLER				P2045 RETURN 3J1-8	J4-80	
	INERTIAL MODE	SWITCH CLOSURE	TO	P2045 I.M. 3J1-5	J4-75	SER
				P2045 RETURN 3J1-6	J4-76	
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	P2045 M.S. 3J1-9	J4-25	SER
				P2045 RETURN 3J1-10	J4-26	SER

TABLE E-2. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
IMS CONTROLLER	GRID MODE	SWITCH CLOSURE	TO	P2045 G.M. 3J1-11	J4-21	SER
				P2045 RETURN 3J1-12	J4-22	SER
	GROUND ALIGN	SWITCH CLOSURE	TO	P2045 G.A. 3J1-3	J4-17	SER
				P2045 RETURN 3J1-4	J4-18	
ARMAMENT RELEASE PANEL	WEAPON QUAN. 80	SWITCH CLOSURE	TO	J202 W.Q. 80 P1-2	J4-63	SER
				J202 RETURN P1-64		
	WEAPON QUAN. 40	SWITCH CLOSURE	TO	J202 W.Q. 40 P1-41	J4-45	SER
				J202 RETURN P1-46		
	WEAPON QUAN. 20	SWITCH CLOSURE	TO	J202 W.Q. 20 P1-40	J4-61	SER
				J202 RETURN P1-62		
	WEAPON QUAN. 10	SWITCH CLOSURE	TO	J202 W.Q. 10 P1-39	J4-41	SER
				J202 RETURN P1-42		
	WEAPON QUAN. 8	SWITCH CLOSURE	TO	J202 W.Q. 8 P1-33	J4-37	SER
				J202 RETURN P1-38		
	WEAPON QUAN. 4	SWITCH CLOSURE	TO	J202 W.Q. 4 P1-32	J4-7	SER
				J202 RETURN P1-8		
	WEAPON QUAN. 2	SWITCH CLOSURE	TO	J202 W.Q. 2 P1-18	J4-33	SER
				J202 RETURN P1-34		
	WEAPON QUAN. 1	SWITCH CLOSURE	TO	J202 W.Q. 1 P1-17	J4-3	SER
				J202 RETURN P1-4		
	WEAPON SPACING 800	SWITCH CLOSURE	TO	J202 W.S. 800 P1-30	J4-47	SER
				J202 RETURN P1-48		
	WEAPON SPACING 400	SWITCH CLOSURE	TO	J202 W.S. 400 P1-29	J4-43	SER
				J202 RETURN P1-44		
	WEAPON SPACING 200	SWITCH CLOSURE	TO	J202 W.S. 200 P1-28	J4-39	SER
				J202 RETURN P1-40		
	WEAPON SPACING 100	SWITCH CLOSURE	TO	J202 W.S. 100 P1-27	J4-35	SER
				J202 RETURN P1-36		
	WEAPON SPACING 80	SWITCH CLOSURE	TO	J202 W.S. 80 P1-16	J4-30	SER
				J202 RETURN P1-95		
	WEAPON SPACING 40	SWITCH CLOSURE	TO	J202 W.S. 40 P1-15	J4-29	SER
				J202 RETURN P1-94		
	WEAPON SPACING 20	SWITCH CLOSURE	TO	J202 W.S. 20 P1-14	J4-11	SER
				J202 RETURN P1-97		
	WEAPON SPACING 10	SWITCH CLOSURE	TO	J202 W.S. 10 P1-13	J4-12	SER
				J202 RETURN P1-96		
	PAIRS SELECTED	SWITCH CLOSURE	TO	J202 P.S. P1-11	J4-19	SER
	PAIRS INT. COMMON	GND	FROM	J202 P.I.C. P1-12	J4-93	
	WEAPONS QUAN. COMMON	GND	FROM	J202 W.Q.C. P1-31	J4-92	

TABLE E-2. (Contd.)

C. Cockpit Area Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
ATTITUDE DIRECTION INDICATOR	COMPUTER RELIABLE	5V DISCRETE	FROM	P272 C.R. J-8	J4-78	LLD
				RETURN J-9	J4-125	
	STEERING ERROR	±2.5 ANALOG	FROM	P272 ±J1-12	J4-71	DIRECT ANALOG E/O AMPLIFIER
				J1-13	J4-72	
AUTO-NAV	COMPUTER RELIABLE	5V DISCRETE		AIRPLANE SWITCHING MATRIX	J4-85	
	STEERING ERROR	±2.5V ANALOG			J4-83	
					J4-84	
		28V DISCRETE			J4-86	
		CHASSIS GND			J4-128	
		CHASSIS GND			J4-127	
		CHASSIS GND			J4-126	
		CHASSIS GND			J4-125	
		CHASSIS GND			J4-124	
		CHASSIS GND			J4-123	
		CHASSIS GND			J4-122	
		CHASSIS GND			J4-121	
		CHASSIS GND			J4-120	
		CHASSIS GND			J4-119	
		CHASSIS GND			J4-118	
		CHASSIS GND			J4-117	
PILOT STICK GRIP	TGT. DESIG. NOT	28VDC DISCRETE	TO	J502 P5-13 (P221-33)	J4-73	HVR
BULLPUP CONTROL STICK	+4V REF	ANALOG		J201 P-G	J4-87	A-D
	-4V REF	ANALOG		J201 P-E	J4-88	A-D
	AZIMUTH RATE	±4VDC ANALOG	TO	J201 P-H	J4-89	A-D
	ELEVATION RATE	±4VDC ANALOG	TO	J201 P-E	J4-90	A-D
	BPC POT CNTR TAP	GND		J201 P-J	J4-91	A-D
FLR CONTROL SET	CURSOR ENABLE	28VDC DISCRETE	FROM	P2025 5J1-h (P211-95)	J4-13	HVD
	ANTENNA SLAVE	28VDC DISCRETE	FROM	P2025 5J1-i (P211-95)	J4-14	HVD
ADVISORY CAUTION PNL	COMPUTER FAIL	28V DISCRETE	FROM	P263 J1-6	J4-77	HVD
	IMU NOT ALIGNED	28V DISCRETE	FROM	P220 J1-15	J4-81	HVD

TABLE E-2. (Contd.)

D. FLR Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
FLR SWEEP	CHANNEL CLOCK	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-f	J4-4	LLD
GENERATOR				P240 COMP 6J6-g	J4-5	(DIFF)
	DATA OUT	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-a	J4-20	LLD
				P240 COMP 6J6-b	J4-21	(DIFF)
	ADDRESS OUT	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-c	J4-14	LLD
				P240 COMP 6J6-d	J4-15	(DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-i	J4-10	LLD
				P240 COMP 6J6-j	J4-11	(DIFF)
	COMPUTER RELIABLE	28VDC DISCRETE	FROM	P240 6J6-g	J4-24	HVD
	DATA IN	50 KHZ DIGITAL	TO	P240 TRUE 6J6-m	J4-18	DER
				P240 COMP 6J6-n	J4-19	DER
	ADDRESS IN	50 KHZ DIGITAL	TO	P240 TRUE 6J6-p	J4-16	DER
				P240 COMP 6J6-q	J4-17	DER
	READY IN	50 KHZ DIGITAL	TO	P240 TRUE 6J6-t	J4-22	DER
				P240 COMP 6J6-u	J4-23	DER
	AGR TEST	28V DISCRETE	FROM	P240 6J6-v	J4-28	HVD
	DATA COMMON	GND	TO	P240 6J6-h	J4-12	
		CHASSIS GND			J4-30	
		CHASSIS GND			J4-31	

TABLE E-2. (Contd.)

E. Right Bay Adapter

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
DOPPLER RADAR ELECTRONICS	DATA IN	50 KHZ DIGITAL	TO	P3052 TRUE 2J3-4	J4-18	DER
				P3052 COMP 2J3-5	J4-19	
	ADDRESS IN	50 KHZ DIGITAL	TO	P3052 TRUE 2J3-6	J4-16	DER
				P3052 COMP 2J3-7	J4-17	DER
	READY IN	50 KHZ DIGITAL	TO	P3052 TRUE 2J3-12	J4-22	DER
				P3052 COMP 2J3-15	J4-23	
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	P3052 TRUE 2J3-20	J4-4	LLD
				P3052 COMP 2J3-22	J4-5	(DIFF)
PROJECTED MAP ELECTRONICS	DATA OUT	50 KHZ DIGITAL	FROM	P3104 TRUE 1J1-15	J4-20	LLD
				P3104 COMP 1J1-16	J4-21	(DIFF)
UNIT	ADDRESS OUT	50 KHZ DIGITAL	FROM	P3104 TRUE 1J1-32	J4-14	LLD
				P3104 COMP 1J1-33	J4-15	(DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	P3104 TRUE 1J1-55	J4-10	LLD
				P3104 COMP 1J1-56	J4-11	(DIFF)
	CLOCK OUT	50 KHZ DIGITAL	FROM	P3104 TRUE 1J1-30	J4-6	LLD
				P3104 COMP 1J1-31	J4-7	(DIFF)
	DATA COMMON	GND	FROM	P3104 1J1-54	J4-12	
		CHASSIS GND			J4-30	
		CHASSIS GND			J4-31	

LIST OF ACRONYMS

ADC	Air data computer
ADI	Attitude direction indicator
AGE	Aerospace ground equipment
AGR	Air-to-ground ranging
ALOFT	Airborne light optical fiber technology
ALOFT/COPPER	Conventional wire interface
ALU	Arithmetic and logic unit
AOA	Angle of attack
ASCU	Armament station control unit
AUTO CAL	Automatic calibration
BARO	Barometric
BIT	Built-in test
Bullpup	Missile
CEP	Circular error probable
CPU	Central processing unit
DEP	Defection error probable
DIG	Doppler inertial gyrocompassing
E/O	Electro-optical
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
FDM	Frequency division multiplexing
FH	Flight hours
FIBER OPTICS	Fiber optics interface
FLR	Forward-looking radar
FO, F.O., F/O	Fiber optics
GFE	Government-furnished equipment
HUD	Head-up display
IBM	International Business Machines Corporation
IC	Integrated circuit
I/DIG	Inertial and doppler inertial gyro compassing
I/O	Input/output
IMS	Inertial measurement set
IMU	Inertial measurement unit
LED	Light-emitting diode
LH	Left hand
LOX	Liquid oxygen
LTV	Vought Division of LTV Aerospace Corporation

MER	Multiple ejector rack
MFHBF	Mean flight hours between failures
MFHBMA	Mean flight hours between maintenance actions
MFS	Master function selector
MRI	Minimum release interval
MRL	Minimum release level
MTBF	Mean time between failures
MUX/DEMUX	Multiplex/demultiplex
NATC	Naval Air Test Center, Patuxent River, MD
NAV	Navigation
NAVAIR	Naval Air Systems Command
NAV/WD	Navigation and weapons delivery
NELC	Naval Electronics Laboratory Center, San Diego, CA
N-S	North to south
NWC	Naval Weapons Center, China Lake, CA
NWDC	Navigation and weapons delivery computer
NWDS	Navigation and weapons delivery system
OFP	Operational flight program
OTP	Operational test program
PCM	Pulse code generator
PD	Photodiode
PGSE	Peculiar ground support equipment
PIN	Positive-intrinsic negative
PMDS	Projected map display set
P/S	Power supply
R&M	Reliability and maintainability
RAD ALT	Radar altimeter
REP	Range error probable
RFI	Radio frequency interference
RH	Right hand
SIDS	Shrike improved display system
S-N	South to north
T	T-connector
TDM	Time division multiplex
TER	Triple ejector rack
WRA	Work replaceable assembly(ies)
WUC	Work unit code
λ	Wavelength

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